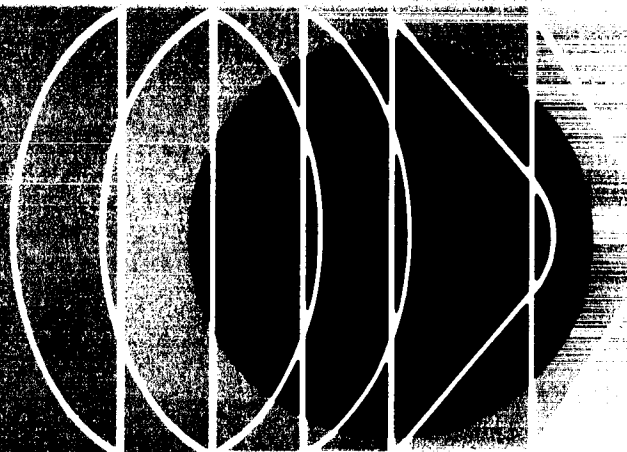SE818-18

REPORT NO. F694

PART A2 PREFERRED DESIGN CONCEPT

VOYAGER
CAPSULE
PHASE B
FINAL REPORT

VOLUME II   CAPSULE BUS SYSTEM

MCDONNELL ASTRONAUTICS

PART A2 PREFERRED DESIGN CONCEPT

16 /P PRES 14 III ½

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VOYAGER
CAPSULE
PHASE B
FINAL REPORT
VOLUME II   CAPSULE BUS SYSTEM

COPY NO. II

MCDONNELL ASTRONAUTICS

REPORT ORGANIZATION

VOYAGER PHASE B FINAL REPORT

The results of the Phase B Voyager Flight Capsule study are organized into several volumes. These are:

Volume I   Summary

Volume II   Capsule Bus System

Volume III   Surface Laboratory System

Volume IV   Entry Science Package

Volume V   System Interfaces

Volume VI   Implementation

This volume, Volume II, describes the McDonnell Douglas preferred design for the Capsule Bus System. It is arranged in 5 parts, A through E, and bound in 11 separate documents, as noted below.

Part A	Preferred Design Concept	2 documents, Parts A_1 and A_2
Part B	Alternatives, Analyses, Selection	5 documents, Parts B_1, B_2, B_3, B_4 and B_5
Part C	Subsystem Functional Descriptions	2 documents, Parts C_1 and C_2
Part D	Operational Support Equipment	1 document
Part E	Reliability	1 document

In order to assist the reader in finding specific material relating to the Capsule Bus System, Figure 1 cross indexes broadly selected subject matter, at the system and subsystem level, through all volumes.

VOLUME II CROSS REFERENCE INDEX

SYSTEM/SUBSYSTEM			PART A — DESCRIPTION OF PREFERRED SYSTEM OBJECTIVES, MISSION, DESIGN, SUBSYSTEMS, OPERATIONS, SUPPORTING FUNCTIONS	PART B — ALTERNATIVES, ANALYSIS AND SELECTION — METHODS TRADE STUDIES, OPTIMIZATION STUDIES RESULTS	PART C — DETAILED DESCRIPTION OF SUBSYSTEM FUNCTIONS	PART D — OPERATIONAL SUPPORT EQUIPMENT — SYSTEM, SUBSYSTEM, LAUNCH COMPLEX, MISSION, HANDLING, SOFTWARE	PART E — RELIABILITY CONSTRAINTS, ANALYSIS, RESULTS, PROGRAM TESTING, CONTROL
CAPSULE BUS SYSTEM							
Mission	Objectives		1.1—Summary	2—Analysis	N/A	1—General	1—Constraints
	Profile		1.2—Summary	2—Analysis 2.4—Selection	N/A	N/A	3.1.1—Analysis
Operations			4—Description by Phase	2.3—Analysis 2.3.7—Landing Site Select	N/A	4.4—LCE Description 4.5—MDE Description	3—Estimates
General			2—Criteria Summary 3.1—Configuration	1—Study Approach 3—Functional Requirements	N/A	3.2—Concept 3.3—Summary 6.1—AHSE	4—Program Requirements 5—Component Reliability
Design	Standardization/Growth		2.5—Summary 11—Future	(See Specific Subsystem Below)	N/A	4.3.8-STC 4.4.8-LCE }Growth 4.5.8-MDE	N/A
	Weight		3.1.2.4—Summary 5—Breakdown	(See Specific Subsystem Below)	N/A	N/A	2.3.2—Reliability vs Weight
Interfaces (See Also Vol. V)			3.1—Summary 9.0—Operational	(See Volume V)	N/A	4.2.1,4.3.5,4.4.5, 4.5.5	N/A
Implementation (See Also Vol. VI)			10—Schedule 8.11-OSE	(See Volume VI)	N/A	(See Specific Subsystem Below)	N/A
Planetary Quarantine			7—General	(See Volume VI, C,7 Sterilization Plan)	N/A	None Required	N/A
O.S.E. (See Also Part D)			8—General (See Also—D1,D2, D3,D4)	(See D2.5-Selection Criteria, D9-Analysis, D10 - Alternatives)	(See D5-Subsystem Level Test Equipment, See Also D4, D6, D7)	Complete OSE Description	(See D4.3.6-STC D4.4.6-LCE D4.5.6-MDE)
SUBSYSTEMS							
Sterilization Canister			3.2.1.1—Description 3.1.2—Summary	5.1—Analysis	1.1	6.1.5.2,6.1.5.3, 6.1.5.6 6.1.5.8—AHSE 6.2.15—Servicing	(See Part C Sections 1.1.1.7 1.1.2.7 1.1.3.7)
Adapter			3.2.1.2—Description 3.1.2—Summary	5.2—Analysis	1.2	None Required	(See Part C, 1.2.7)
Aeroshell			3.2.1.3—Description	4.1—Configuration	1.3	None Required	(See Part C, 1.3.7)

Figure 1

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Subsystem	Description / Summary	Selection / Analysis	No.	Test & Support Equipment	Reference
Lander	3.1.2—Summary 3.2.1.4—Description	Selection 4.6—Separation 5.3.1—Structure 5.3.2—Heat Shield 4.2—Configuration Selection 5.4—Analysis	1.4	6.1.5.9—Fixture	(See Part C, 1.4.7)
Telecommunications	3.2.2.1—Description	4.9—In-Flight Monitoring 5.5—Analysis	2—Telemetry 3—Radio 4—Antenna 5—Data Storage 6—Command	4.3.9.1—STC Console 5.7—Test Set	(See Part C, Sections 2.1.7, 2.2.7, 2.3.7, 3.1.7, 3.2.7, 4.5, 5.1.7, 5.2.7, 6.1.7, 6.2.7)
Power	3.2.2.2—Description	5.6—Analysis	7	4.3.9.1—STC Console 5.3—Test Set	(See Part C, Sect. 7.7)
Sequencing and Timing	3.2.2.3—Description	5.7—Analysis	8	4.3.9.1—STC Console 5.4—Test Set	(See Part C Sections 8.1.7, 8.2.7)
Guidance and Control	3.2.2.4—Description	4.7—De-orbit Attitude Reqm't. 5.8—Analysis	9	4.3.9.1—STC Console 5.5—Test Set	(See Part C, 9.7)
Radar	3.2.2.5—Description	5.9—Analysis	10	4.3.9.1—STC Console 5.6—Test Set	(See Part C, Sections 10.1.7, 10.2.7)
Aerodynamic Decelerator	3.2.3—Description	4.4—Selection 5.10—Analysis	11	None Required	(See Part C, 11.7)
Pyrotechnics	3.2.4—Description	5.11—Analysis	12	4.3.9.1—STC Console 5.9—Test Set	(See Part C, 12.7.1)
Thermal Control	3.2.5—Description	5.12—Analysis	13	4.3.9.1—STC Console 5.8—Test Set	(See Part C, 13.6)
De-orbit Propulsion	3.2.6.1—Description	5.13.1—Analysis	14	5.10—Test Set 6.1.5.10—AHSE	(See Part B, 5.13.4.5) (See Part C, 14.7)
Reaction Control	3.2.6.2—Description	5.13.2—Analysis	15	5.10—Test Set 6.2—Servicing	(See Part B, 5.13.4.5) (See Part C, 15.7)
Terminal Propulsion	3.2.6.3—Description	4.3—Configuration Selection 4.5—Terminal Deceleration 5.13.3—Analysis	16	4.3.9.1—STC Console 5.10—Test Set 6.2—Servicing	(See Part B, 5.13.4.5) (See Part C, 16.7)
Packaging and Cabling	3.2.7—Description	5.14—Analysis	17	4.3.9.8—Special Purpose Complex Equipment	Not Required

Note: Parentheses Refer Reader to Volumes/Parts Outside of the Respective Notation

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APPENDIX B

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7-1 through 7-11

8-1 through 8-39

9-1 through 9-8

10-1 through 10-28

11-1 through 11-14

Appendix A: 1 through 21

Appendix B: 1 through 16

SECTION 7

PLANETARY QUARANTINE

Quarantine of Mars is accomplished by limiting the contamination state of the exploratory vehicles approaching the planet. Landers represent the greatest contamination threat and therefore must be sterile when entering the Martian environment. The VOYAGER Flight Capsule will be sterilized by dry heat before launch and will be contained within a microbiological barrier until ready for entry.

This places new requirements on the design, development, and production of spacecraft equipment. The Capsule Bus contractor must produce a system that can be confidently certified as sterile. During the past study effort we have established and used design guidelines to assure that the CBS configuration is compatible with the heat and decontamination criteria. We have used a contamination sensitivity analysis to isolate the critical events and factors which need to be controlled. Also, we have developed a Sterilization Plan which insures that the Surface Laboratory and the Landing Capsule are sterile.

The sections below deal with the contamination factors and the design considerations which they impose on the Capsule Bus. The Sterilization Plan, which combines the sterilization requirements with manufacturing, testing and launch site operations, is summarized below and is presented in its entirety in Volume VI.

Figure 7-1 shows the progression of constraints and requirements which make the design for sterility and the contamination control real necessities.

7.1 CONTAMINATION FACTORS – The purpose of this section is to examine the sensitive factors in terms of their influence on the Capsule Bus from the design to Martian operation.

7.1.1 Initial Contamination – The initial internal burden of contamination of piece parts and materials significantly contributes to the total CBS burden, depending on the assembly environment and the timing of the Flight Acceptance (FA) heat cycle, which is used to reduce the accumulated bio-burden during assembly. With assembly in ultra-clean rooms (Class 100 or better) and late FA heat cycling, initial burdens represent the large proportion of contamination possibilities. This is particularly true of the CBS, which has a large number of connectors and handfinished piece parts. Assembly in ordinary clean rooms (Class 100,000 or worse) loads the system quickly and overshadows the initial burdens. In either case initial burdens must be known (or conservative estimates determined) to make contamination reports as complete and accurate as possible.

7-1

FLOW OF PLANETARY QUARANTINE CONSTRAINTS AND REQUIRED CONTAMINATION CONTROLS FOR LANDING CAPSULES

Planetary Exploration – Life Detection Goals

COSPAR International Agreement

NASA Planetary Quarantine Policy

Mars Planetary Quarantine Policy

Landing Capsule Contamination Constraints

VOYAGER Spacecraft Contamination Constraints

Sterile Landing Capsule Constraint

Lander Recontamination Constraint

Sterile CBS Requirement

Sterile SLS Requirement

Sterile ESP Requirement

Sterilization Canister Requirements

Requirement for Terminal Heat Sterilization

Determination of Number of Microorganisms

Adequacy of Heat Sterilization

Contamination Data Bank

Demonstration by Engineering Models

Contamination Control System

Critical Control Factors

Initial Contamination

Effects of Storage

Handling

Retention Factors

Decontamination

Bioclean Facilities
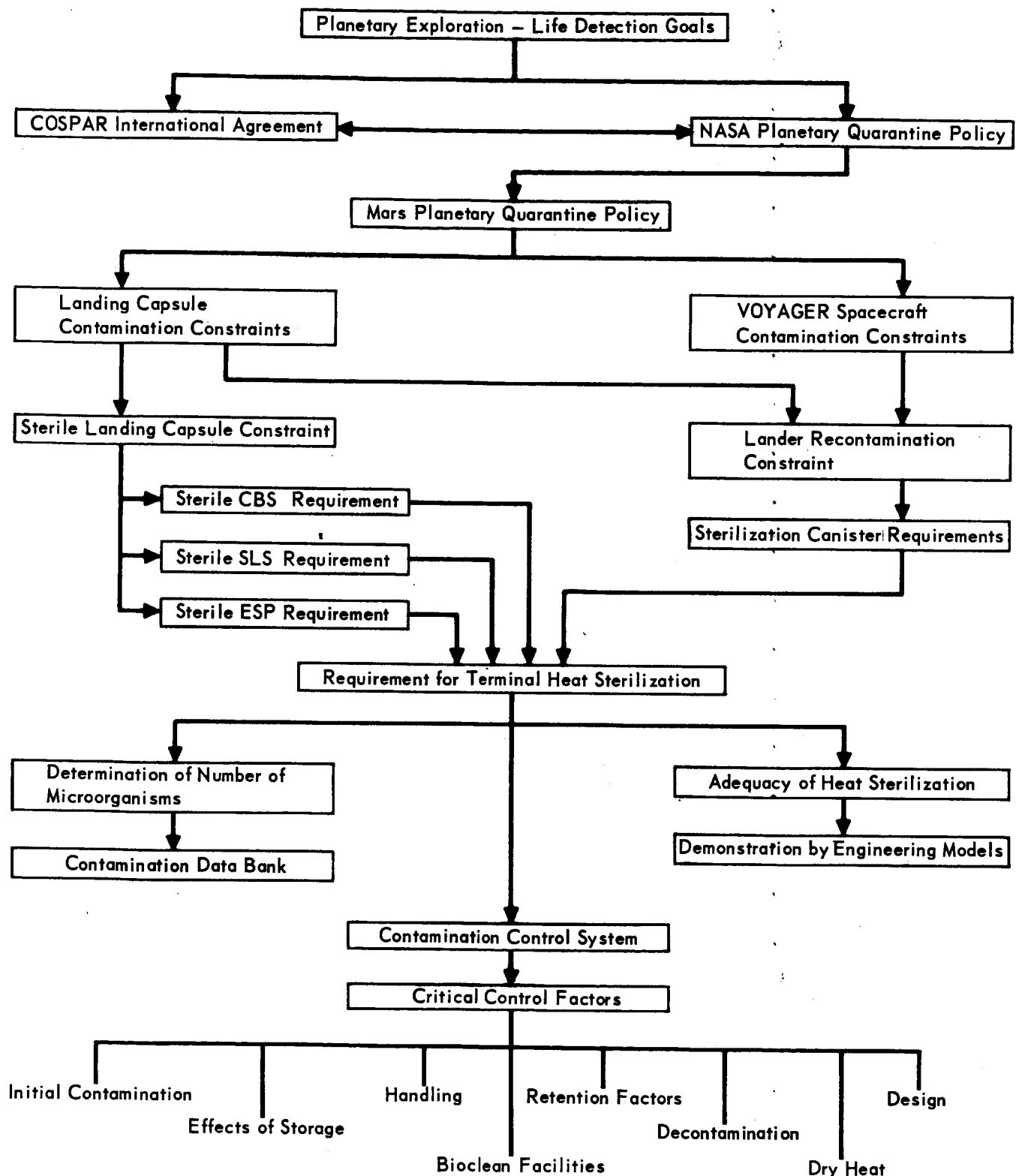
Dry Heat

Design

Figure 7-1

7-2

7.1.2 <u>Effect of Storage</u> - Each item used in the CBS will be stored several times as assembly progresses and as work alternates between subsystems. Vegetative cells die in storage at rates estimated as high as 99 per cent per year, depending on conditions such as humidity, temperature and available light. Spores are substantially hardier, a total of perhaps only 10 per cent dying off per year. To provide a conservative estimate of the CBS burden, the die-off of vegetative cells only will be considered; that is, all arriving spores plus the surviving vegetative cells will be assumed to give the contamination count. McDonnell will take advantage of the low humidity and moderate temperatures of the bonded storage areas and double wrapped packaging to reduce vegetative counts.

7.1.3 <u>Handling</u> - Contact by human operators offers the greatest contamination threat to the CBS. Touching parts with the bare hands and arms deposits organisms by the hundreds of thousands per square inch and frequently inoculates nutrient media in the laboratory so profusely that counting is hopeless. Sterile gloves reduce the contamination hazard to a livable average of about 4 organisms per square inch per touch. Therefore, regardless of the choice of assembly room conditions and other burden-sensitive factors, hand and arm protection is required.

7.1.4 <u>Bio-Clean Facilities</u> - Contamination of exposed parts and assemblies by airborne organisms is a hazard second only to handling. Contamination can be controlled within several types of clean facilities which range in size from a small workbench to large rooms with sophisticated controls. They vary in effectiveness from adequate particulate control to total biological control, such as with a sterile assembler.

There are two periods during the manufacturing and testing of the CBS in which the effect of clean facilities was evaluated. The first of these is the time from piece part acquisition until flight acceptance heat cycling. Here, good particulate control is required to produce high quality hardware but bioburden determination is less critical. Contamination can be estimated by using limited monitoring data coupled with microbiology laboratory and past clean room experience. Class 100,000 facilities are adequate during this period.

In effect there are three clean room operation alternatives: optimizing the level of assembly at which FA heating takes place; upgrading clean facilities for better contamination control and to reduce the heating period; and sterilizing the ESP and SLS prior to integration with the Capsule Bus. McDonnell's choices were made on the basis of: optimizing the ease of assembly and test; reducing facilities required; and providing adequate contamination control.

7-3

In order to optimize ease of assembly and test and to reduce additional facil-
ities, the CBS is preferably assembled to near completion in a "normal" clean
environment (Class 100,000). Subsystem checks and system tests are also performed
in that facility, and mating with the capsule bus is completed. Then the CBS is
subjected to the FA heat cycle. Class 100 facilities are then used during the
remaining system confidence tests and at all times prior to terminal heat steriliza-
tion. In addition to reducing the facilities required and making assembly easier,
this method allows the CBS contractor to simulate terminal sterilization during the
FA cycle and improves reliability by not requiring disassembly.

7.1.5 <u>Retention Factors</u> - Capsule Bus materials display a spectrum of electro-
static properties. The native ability of materials to attract and retain airborne
particles (both viable and non-viable) will be considered during design and clean
room assembly of the CBS. It has been demonstrated, for example, that certain
plastics retain ten times as many organisms as most metals. Retention factors will
be approximated from experimental data and combined with the measured arrival rate
of airborne organisms.

7.1.6 <u>Decontamination</u> - The number of microorganisms which accumulates on the
exposed surfaces of the CBS can be reduced by as much as four orders of magnitude
by gaseous decontamination. Ethylene Oxide (ETO) is used as a planned control
mechanism as specified in JPL VOL. 50503 ETS, to lower surface burdens prior to the
flight acceptance and terminal heat cycles. It may also be used, with considerable
discretion, for recovering from unplanned contamination control breakdowns. ETO is
not freely or indiscriminately used in lieu of limiting the arrival and disposition
of microorganisms.

7.1.7 <u>Dry Heat Cycling</u> - Dry heat applied at proper temperatures and times is used
twice during the CBS assembly. A flight acceptance heat cycle is planned at an
incomplete level of assembly which effectively reduces the bioburden to zero and
serves as a starting point for biomonitoring and precise contamination control.
Prior to launch, a terminal sterilization heat cycle lowers the contamination of
the Flight Capsule, to a probabilistic level, i.e. there will be only one chance in
a thousand that a single spore remains viable after the heat application.

Constrained by the final number of organisms allowed prior to the final heat
cycle, terminal sterilization must meet time and temperature specifications for kill
effectiveness. If the accumulated organisms can be shown to be fewer than the
limit, time for sterilization may be substantially reduced at NASA's discretion.

7-4

This would improve confidence in the system and make later heat recycles less detrimental.

The flight acceptance heat cycle could be employed at almost any point during the assembly process. However, the earlier it is applied, the sooner problems will begin to be uncovered. Applied later in assembly, it simulates the terminal sterilization cycle more closely and reduces the scheduled time in the Class 100 environment which must follow. As described in 7.1.4 above, the timing of this heat cycle has been selected to optimize facility schedule, manufacturing efficiency, contamination control, and to preempt terminal sterilization problems.

7.2 DESIGN FOR STERILITY - The CBS design details must be compatible with dry heat and ETO. Not only piece parts and materials must qualify, but subassemblies, assemblies, etc., and the entire system itself must be impervious to damage or change when applying these procedures. In addition, the rate of contamination accumulation, the accessibility of surfaces to gas diffusion, and the efficiency of heat transfer all influence or create design criteria.

7.2.1 Structure - It is generally conceded that structure represents the least problem in meeting sterile design criteria. It is, nonetheless, important that it does so. For example, bioload buildup and decontamination effectiveness are profoundly affected by structural simplicity, but the number of steps of operation required during assembly, and by the areas which are "internalized" during the assembly process. Structure is responsible for proper transfer of sterilizing heat to mounted experiments and subsystems. During heat cycling, poorly designed structure sometimes imposes severe mechanical stresses on subsystems, resulting in a variety of mechanical devices, particularly to the structure of deployable and extendible ones.

The CBS contractor is responsible for specifying design requirements which anticipate and preclude such problems. During McDonnell Phase B study, the VOYAGER Planetary Quarantine office has developed design practices with this in mind and has issued the design guidelines of Figure 7-2 to the system engineering staff. These guidelines will become an integral part of design review values during detailed design of the Capsule Bus System during Phase C and D.

7.2.2 Subsystem - Capsule Bus Subsystems are described in Section 3 above wherein the sterilization requirements of each subsystem are considered. Figure 7-3 summarizes the major development items required to make each subsystem sterilizable and the CBS function which each affects.

The major subsystem design considerations for the CBS contractor to assure

7-5

GENERAL GUIDELINES - STERILE VOYAGER DESIGN

Guidelines - The following general rules for designing sterilizable spacecraft components are applicable to the VOYAGER Systems and Structure and will serve as the basis of design review by the McDonnell Planetary Quarantine Office.

The number of assembly contact points at all levels of assembly should be minimized to provide good heat transmission paths for equalizing temperature rates during heat sterilization and to prevent occluding of contaminated surfaces. (Contact points must be sufficient to maintain structural integrity, however). Specifically, contact points may be reduced as follows:

Replace bolts and fasteners with rivets, when possible.

Replace rivets with welds, when possible.

Keep surfaces simple with smooth curvature.

Avoid compound curves.

The number and volume of voids within the structure should be minimized to provide optimal heat conduction and to reduce the number of occluded organisms.

The number of assembly steps should be reduced to a practical minimum to eliminate excess handling and fallout exposure.

Occluded and mated areas should be minimized by good design practice. Specific items include:

Reducing the number of assembly contact points.

Adding gas diffusion holes in containers, covers, and packages which do not have to be sealed.

The number of electrical and plumbing connectors should be minimized. These are notorious contamination collectors because of the added handling they receive and the encapsulation of microorganisms when they are "made".

Heat sterilization compatibility should be considered by:

Minimizing the number of bi-metallic adjoining surfaces.

Designing for efficient heat flow

Designing for dimensional stability by using proper materials, expansion joints, heat sinks, thermal switches, fins, insulation, and symmetry.

Reviewing heat sensitive components for possible changes in concept, material, and manufacture.

Determining expansion/contraction envelopes, especially on all plumbing and electrical lines.

Figure 7-2

7-6

IDENTIFICATION OF CBS MAJOR DEVELOPMENT

WORK IMPOSED BY STERILIZATION REQUIREMENTS

DESCRIPTION	MAJOR DEVELOPMENT REQUIRED	FUNCTION AFFECTED
1. Structure		
a. Sterilization	Seals and Venting	Bio-barrier
b. Adapter	None	NA
c. Aeroshell	None	NA
d. Lander	None	NA
2. Subsystems		
a. Telecommunications	Data Storage	Information Retrieval
b. Power	Ag – Zn Batteries	All powered subsystems
c. Sequence/Timing	Memory	All timed systems
d. Guidance and Control	Gyros and Memory	Attitude Control
e. Radar	Transmitter and Components	Landing Phases
f. Aerodynamic Decelerator	None	–
g. Pyrotechnics	Gas Generators	Parachute and auto-activiated batteries
h. Thermal Control	Metallic Coatings	All subsystems
i. Deorbit Propulsion	None	–
j. Reaction Control	Liquid Propellant and Tanks	Entry Attitude
k. Terminal Propulsion	Liquid Propellant and Tanks	Landing
l. Structural Mechanical	None	–
m. Packaging/Cabling	None	–

Figure 7-3

7-7

sterilization compatibility are: identifying long lead time development articles, and specifying sterilization compatibility of subsystems as entities, and as integral parts of the Capsule Bus system. Subsystem design also plays an important role in the sterilization plan, influencing the selection and timing of contamination control elements and the implementation of heating for bioload reduction.

7.3 MAINTENANCE OF STERILITY - Following integration with the Surface Laboratory and the Entry Science Package, the Capsule Bus will be enclosed in the Sterilization canister and heat sterilized. The canister bars access and impairs communication so that the landing capsule must be remotely tested to verify that each system has withstood the heat soak. In-flight tests prior to separation will add to the remote testing burden. Inaccessibility also requires more accurate and reliable systems which do not need adjustment and recalibration. The telecommunication subassembly will operate in the prelaunch mode and will verify system operation. There will be no possibility of checking propulsion, pyrotechnics and decelerators, so confidence in the survivability of those subsystems must be gained in type approval tests. Sterility is verified during prelaunch operations and through launch and earth orbit insertion by monitoring the pressure within the Sterilization Canister.

The sterility of the Capsule Bus, during interplanetary cruise, cannot be directly monitored with any existing instrumentation or microbiological experiment. However it can be inferred by computing the probability of recontamination from all identifiable sources.

The McDonnell team has conducted a three-part effort to begin the preparation of the technological base which is required:

Study of the Physics of Recontamination - A study was performed to consider the physical properties of microbes, the force fields in the vicinity of a spacecraft, and the potential recontamination mechanisms. The results of this study are reported in References 7-1, 7-2, and 7-3. Its objectives were:

   a. to define the areas that are significant in the recontamination of the VOYAGER Capsule and

   b. to provide the rationale for the advanced study and experimentation of the physical phenomena associated with microbe motion and recontamination modes.

We reviewed the basic nature of recontamination modes to define the physical forces involved and to establish their relative order of magnitude. Additional analytical and experimental studies are required to quantify those microbial properties and recontamination modes considered to be critical for the Capsule Bus. These studies

7-8

could include such subjects as an investigation of the microbial adhesive forces on spacecraft surfaces and the free surface charging of microbes in a hard vacuum.

Preliminary Analysis of the Probability of Capsule Recontamination - A study was performed to identify the potential modes of Capsule recontamination and to plan a model format to compute their probabilities of recontaminating the Capsule. The results of this study are reported in Reference 7-4. The analyses and the models of contamination modes were preliminary and qualitative. The analyses have identified those areas which require more model work and quantification and some of the more important hardware design ramifications.

Presuming that meteoroid defense will be required to maintain the required biological environment for the Capsule (Canister punctures caused by meteoroid penetrations have been identified as a possible source of recontamination), a study was performed to determine the theoretical cost in weight and design complexity of providing meteoroid protection. The resulting data permits system studies to be conducted wherein the weight/complexity associated with meteoroid defense can be traded-off with the required level of recontamination probability.

Analysis of Meteoroid Defense Construction Design Requirements and Techniques - A study was performed, based on the JPL-specified meteoroid environment and the NASA/MSC criteria for penetration analysis, which resulted in the generation of meteoroid defense parametric design data. The data, presented in Reference 7-3, shows 'probability of no penetration' as a function of: the material used, the space between 2-sheet structures, the structural area, and the time exposed to meteoroid environments. The study also utilized the NASA/LRC criteria for non-filled 2-sheet aluminum construction and compared the difference in their penetration probability levels.

7.4 STERILIZATION PLAN - The ultimate procedure for producing a sterile Capsule Bus which meets NASA requirements was derived from a thorough analysis of the contamination factors, design requirements, practical manufacturing and testing procedures, and the qualification programs presently in work. That procedure is the preferred Sterilization Plan, which is detailed in Part C, Section 7 of Volume VI. Paraphrasing that plan, there is a need to:

Assure Reliability of Sterilizable Components by conducting Type Approval qualification tests on all piece parts, materials, subassemblies, assemblies and systems which are candidate types for flight hardware.

Control Contamination by carefully selecting and training clean room personnel;

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by imposing control procedures on major subcontractors, by designing the CBS for low burden accumulation rates and easy contamination; by collecting contamination data during receipt, inspection, checking, assembly and system testing; by assembling the CBS in a Class 100,000 clean facility; by performing flight acceptance heat cycling after the system is essentially completed; by monitoring assembly procedures, test procedures and personnel cleanliness and clothing procedures; by completing assembly and subsystems testing prior to flight acceptance heat and verifying performance after heat, thereby simulating terminal heat; by decontaminating the CBS at predetermined points; by establishing bioburden limits at progressive stages of manufacture, based on data from test vehicles; by creating a contamination data system for daily and periodic burden reports; by using an in-factory Class 100 facility for continued system tests and environmental tests after flight acceptance heating; by shipping the lightly contaminated capsule lander in an environmentally controlled shipping canister and by using Class 100 facilities at KSC.

Terminally Sterilize the Capsule Lander by first determining the contamination load, using assembly room bioassays and coupon assays and by then applying heat as specified by NASA constraints to reduce contamination to the specified probabilistic level.

Maintain Sterility by designing a Sterilization Canister which keeps a positive differential pressure inside at all times, from sterilization through launch; by employing CBS, SLS, and ESP systems which require no post-sterilization adjustment; by monitoring pressure and seal integrity continuously; by using separation techniques which generate no debris to contaminate the planet or Capsule Lander and which will not allow contamination crossover from the unsterile spacecraft.

7-10

REFERENCES

7-1 GE Document TIR 8126-232, "Study of the Physics of Recontamination" by David Enlow, dated July 14, 1967

7-2 GE Document TIR 8122-949, "Properties Influencing Bacterial Adhesion" by Paul Kubask, dated July 14, 1967

7-3 GE Document TIR 8128-623, "Satellite Charge Build-Up" by Walter Sawchuck, dated August 2, 1967

7-4 GE Document TIR 8144-232, "Capsule Recontamination Modeling" by George Meyer and Michael Cohen, dated August 1, 1967

7-5 GE Document TIR 8152-2374, "Meteoroid Defense Requirements and Analysis" by Edward Bruce, dated June 30, 1967

OPERATIONAL SUPPORT EQUIPMENT (OSE) DESCRIPTION

Our Capsule Bus OSE design has been selected as a balanced approach to meeting the VOYAGER program objectives and the JPL Capsule Bus System requirements and constraints in a manner that is compatible with Capsule Bus and Spacecraft integrated operations, and which will meet schedule and cost objectives. We have analyzed the requirements and constraints specified by JPL, established Capsule Bus OSE objectives, derived additional requirements to assure mission success, and identified unique problems that require design solution.

The design characteristics which reflect our solution to Capsule Bus OSE requirements are summarized in Figure 8-1. Highlights of our approach are:

o A centralized, computer controlled System Test Complex that performs automatic test sequencing, response analysis, automatic limit and alarm monitoring, data suppression, and OSE self-check.

o Automated Subsystem Test Sets that establish an accurate, repeatable test data base for fault isolation and trend analysis from factory through mission operations.

o Design and packaging of system level test equipment in accordance with a "factory-to-pad" test concept which minimizes the requirement for subsystem test equipment at KSC.

8.1 <u>OBJECTIVES AND REQUIREMENTS</u> - The ultimate goal of Capsule Bus Operational Support Equipment is to provide the maximum probability of on-schedule accomplishment of VOYAGER's scientific mission, and successful acquisition of the mission data. Recognizing the vital role of Operational Support Equipment and Mission Dependent Equipment in attaining these goals, we have established fundamental objectives for the design, development, and implementation of Capsule Bus OSE, based upon VOYAGER program studies and our Mercury/Gemini experience. The following are considered among the foremost objectives for Capsule Bus OSE:

a) Provide the highest practical probability of launch-on-time (Key to attainment of this objective is the reliability, speed, and availability of the OSE used for prelaunch and launch operations at KSC). b) Provide test continuity, elimination of test variables, and a continuous test history as the capsule and its components flow from factory through launch and mission operations. c) Provide growth potential and flexibility for future missions with minimum change.

8-1

OSE DESIGN CHARACTERISTICS SUMMARY

SUBSYSTEM TEST EQUIPMENT (SSTE)	• Direct analog hookup to flight subsystems. • Digital displays + hard copy print out. • Common design usable at all test sites. • Selected subsystem test sets automated. • Manual backup capability. • OSE self check. • Automatic alarm monitoring of critical parameters. • Test mode and data time tagged and recorded for data bank.
SYSTEM TEST COMPLEX (STC)	• Central computer used for automatic test sequence control, data monitoring and evaluation. • CRT display + keyboard + hard copy print out in engineering units. • Manual backup capability. • System test at KSC without subsystem test sets. • TCP computer used for TM data processing. • OSE self check. • Automatic alarm monitoring. • Monitors pad operations plus CB storage area.
LAUNCH COMPLEX EQUIPMENT (LCE)	• Launch monitor console in LCC for launch conditioning of CB. • Uses STC for remote monitor of flight TM • Direct hardlines for critical data. • Uses S/C flyaway umbilical + RF data link for launch pad data transmission. • Hardwired automatic alarm and safeing of critical functions. • Fault isolation to capsule or OSE. • Provides emergency power to CB, and OSE.
MISSION DEPENDENT EQUIPMENT (MDE)	• Uses software for CB decommutation • Special purpose hardware preprocesses CB telemetry for compatibility with TCP.
ASSY, HDNG, SHIPPING AND SERVICING (AHSE)	• Transporter capable of air, barge or helicopter usage. • Basic handling modules plus adapters for multifunction usage. • Servicing equipment mobile and self contained. • Provides emergency propellant dump at launch pad and ESF.
SOFTWARE	• Building block approach to software packaging and development. • Integrated management of CB, SLS, ESP test software.

Figure 8—1

8—2

Our design is based on compliance with the requirements and constraints specified by JPL, as described in "Applicable Documents", Part D, Section 2.1. But successful implementation of the VOYAGER program requires more than compliance with the specified requirements. We have analyzed the significant problems presented by program requirements, VOYAGER systems integration, Capsule Bus configuration, and the CBS Integrated Test Plan in order to derive the additional requirements that will contribute the extra performance margin necessary to assure VOYAGER mission success. Figure 8.1-1 summarizes the objectives, derived requirements, and constraints which form the basis for our Capsule OSE design.

8.2 SYSTEM UTILIZATION - Because the OSE design concept is so fundamentally dependent on test and ground operations, a brief description of OSE utilization is provided.

Capsule Bus (CB) Operational Support Equipment is designed to support development and flight acceptance testing from factory through launch. During the mission and landing, Mission Dependent Equipment (MDE) provides continued operational support. An overview of the capsule test flow and the utilization of Operational Support Equipment at the major test sites is illustrated in Figure 8.2-1.

The basic OSE categories and their functions are in accordance with the JPL constraints document, and as further defined below:

Subsystem Test Equipment (SSTE) - Test equipment related primarily to the testing of a particular flight subsystem. For the CB, SSTE is composed of Subsystem Test Sets and Subsystem Test Consoles. The Subsystem Test Sets (SSTS) are used for pre-delivery acceptance (PDA) of modules at principal subsystem vendors; at the CB contractor's factory for Equipment Functional Check (EFC) of delivered flight hardware prior to capsule installation, and for subsystem level tests during module and capsule buildup. The Subsystem Test Consoles are used for integrated systems tests in conjunction with the System Test Complex below.

System Test Complex (STC) - Equipment used for integrated system tests and simulated missions at the CB contractor's factory and KSC. Also used for Launch Complex Equipment (LCE) functions to reduce quantity of LCE required. STC consists of selected items of SSTE plus OSE system elements.

Launch Complex Equipment (LCE) - Supplements the STC for control and monitor of operations on the launch pad and at the KSC Explosive Safe Facility (ESF). Provides power, alarm warning, and emergency control of the capsule prior to launch.

Mission Dependent Equipment (MDE) - Used to conduct operations from the Deep Space Network (DSN) and Space Flight Operations Facility (SFOF) during cruise and mission operations. Also used in the STC to establish compatibility between Capsule

8-3

CAPSULE BUS OPERATIONAL SUPPORT EQUIPMENT –
SUMMARY OF MAJOR OBJECTIVES AND REQUIREMENTS

OBJECTIVES, CONSTRAINTS, AND DERIVED REQUIREMENTS

OBJECTIVES
- Provide the highest practical probability of launch-on-time.
- Provide some measure of mission success, regardless of circumstances.
- Provide test continuity, elimination of test variables and a continuous test history as the capsule and its components flow from factory through launch and mission operations.
- Protect personnel, flight systems, and OSE from hazard or damage due to OSE failure or human error.
- Achieve maximum commonality of functional modules, utilization of common design, and avoid unnecessary duplication of equipment.
- Accommodate subsystem changes and provide growth potential and flexibility for future missions with minimum change.
- Design and package OSE to conserve space in integrated operations areas, and to provide compatibility with other elements of the VOYAGER system.
- Incorporate effective and economical maintainability provisions to ensure the operational availability of the OSE.
- Minimize development risk by maximum use of OSE designs and off-the-shelf components that have proven performance on the Mariner, Lunar Orbiter, Gemini, and other NASA programs. Use existing hardware where consistent with performance requirements.
- Demonstrate OSE and software compatibility with the Capsule, SLS, Spacecraft, and DSIF prior to acceptance test of the first flight vehicle.
- Employ practical cost solutions to optimize the cost-effectiveness ratio of Capsule Bus OSE.

CONSTRAINTS
- The launch opportunity, launch window, and launch period are time-limited.
- Complex 39 will be used at Kennedy Space Center (KSC).
- Planetary quarantine requirements must not be degraded.
- Two planetary vehicles will be launched on a single launch vehicle.

DERIVED REQUIREMENTS – CAPSULE BUS OSE
- Mission critical Operational Support Equipment (OSE) must be allocated a P_s based on reliability analysis of launch operation and supporting equipment. Mission critical OSE is defined as that equipment or software, (including Mission Dependent Equipment), whose failure could delay or abort a launch during the terminal count or cause degradation of the mission after launch.
- After encapsulation of the Flight Capsule in the canister, the Flight Capsule System Test Complex (STC) must be capable of performing integrated system tests and fault isolation, and monitoring critical parameters.
- OSE required inside the Class 100 Rooms must be designed for minimum contamination of the Capsule Bus and Class 100 environment.
- LCE must provide fault isolation and decision-making capability to the level required for launch commitments.
- Subsystem OSE must be designed for performance margin testing and provide a historical data base readily correlated with system test data after Flight Capsule encapsulation.
- The Capsule Bus System Test Complex (STC) must be capable of monitoring and checkout of two Capsule Buses on the Pad and be available for preiodic checkout of two Capsule Buses in storage.
- Human Engineering must be performed on all OSE designs to determine the best method of displaying information and arrangement of controls in order to minimize operator error and provide maximum safety for personnel and equipment.

DERIVED REQUIREMENTS – SLS AND SPACECRAFT CONTRACTORS
- During Planetary Vehicle (PV) systems test and launch pad operations, the SC Contractor's STC must strip out and reroute Capsule Bus TM data to the Capsule Bus System Test Complex (STC).
- The SC Contractor's flyaway umbilical must contain an adequate number of pins for handling critical signals and RF coax-connectors for launch pad operations.
- The SLS Contractor must provide test point access for analysis and fault isolation during Flight Capsule integration and environmental testing.
- The SC and SLS Contractors must provide interface simulators which precisely simulate signals and loads for checking compatibility prior to mate.

SYSTEM TEST COMPLEX (STC)
- Acquiring, processing, distributing, test facility data for real-time and n general-purpose computer system.
- Providing capability to vary Capsule signals, for required performance tes
- Isolating trouble to the provisioned
- Centrally controlling or directing the individually or in combination, throu of a system test by the use of a gen
- Manually controlling the Capsule or to any operating mode, and in any o provided for by the normal capsule t
- Provide growth capability to accept for the 1975 launch opportunity.
- Providing safeguards to prevent the any of the subsystems due to improp STC element malfunction or failure;
- Provide capability for disassembly, the time required to transport the Ca

SUBSYSTEM TEST EQUIPMENT (SST
- Complete testing of its subsystem i tions as provided for by the normal
- Varying subsystem parameters for p
- Isolating trouble to the subassembly
- Manually controlling the subsystem sequence provided for by the norma
- Providing subsystem power normall subsystem.
- Performing all required test routine and providing safeguards against in malfunction or failure.
- Providing connecting subsystem sin subsystem test.
- Monitoring and selective recording normal subsystem test circuitry.
- Providing alarm monitoring during s
- Identify and record all test data for tional verification.
- Provide Self test and calibration co prior to or during testing.

MISSION DEPENDENT EQUIPMENT
- MDE used in the STC and LCE is i Network.
- Demodulate the telemetry signal as provide the telemetry bit stream to
- Verify the validity of commands rec
- Transmit commands to DSIF transm
- Verify command transmission bit by inhibit command if error is detecte
- Provide capability for remote monit and displays, and operate in an au
- Provide a Capsule radio subsystem detector to simulate the capsule in
- Provide for interfacing with a gene telemetry data and decoding of con

8-4-1

ind displaying of Capsule OSE, and
n-real time analysis by the use of the

parameters, or externally supplied
ting.
pare replacement level.
Capsule or any of its subsystems,
jh a complete or selected portion
ral purpose computer system.
iny combination of its subsystems,
erating mode, and in any sequence,
ist circuitry.
he anticipated requirements of a CB

xccurrence of damage to a Capsule or
ir sequencing of test steps, or due to
provide self test without test interruption.
transport, and setup of the STC within
psule to KSC and prepare it for test.

E)
all subsystem and system test configura-
ubsystem and system test circuitry.
rformance margin testing.
replacement level.
:o any operating mode and in any
subsystem test circuitry.
supplied by the spacecraft power

expeditiously, correctly and repeatably
proper sequencing and against OSE

iulated interface to enable midependent

if subsystem functions provided by the

jbsystem tests.
off-line analyses for design and opera-

pability to validate the support equipment

(MDE)
Jentical to that used in the Deep Space

received from the DSIF receiver and
other elements of the ground systems.
:eived from SFOF.
itter.
/ bit on output to DSIF transmitter and
J.
toring of all controls, switch positions,
tomatic and a manual mode.
1, telemetry modulator, and a command
terface with the DSIF.
iral purpose computer for generation of
nmands.

LAUNCH COMPLEX EQUIPMENT (LCE)

- Design to a P_s allocation determined by reliability and operations analysis.
- Provide complete testing of the Flight Capsule, as provided by the Capsule umbilical and RF test circuitry, and limited Capsule testing during "RF silence."
- Automatically control the Capsule in the terminal portion of a simulated or real countdown with manual hold and reset capability.
- Supply external Capsule power and power switching control, and provide for controlled transfer to emergency main power sources, main power isolation, and conditioning of the Capsule to a safe mode in event of failure and subsequent resumption of facility power.
- Provide continuous indications, controls and alarms, with or without Capsule or facility power on, of all Capsule ground functions related to Capsule or personnel safety; e.g., pyrotechnic "arm-safe", propellant and gas pressures, battery voltage, detection of toxic or explosive vapors.
- Provide a communication system between the launch control center, launch pad, and the planetary operations control center.
- Self-test without interruptions of Capsule operation, and fault isolation to the Capsule level.
- Decoding, recording, time tagging, and displaying, independent of other data control centers of all: 1) Capsule inputs supplied by the LCE, 2) capsule data available at the launch complex, 3) facility supplied power to the LCE, 4) signals supplied to or from all other interconnecting equipment, 5) external instrumentation data, 6) synchronizing signals from facility and ETR time codes.

ASSEMBLY, HANDLING, SHIPPING AND SERVICING EQUIPMENT (AHSE)

- Position (hoist and rotate) capsule bus, aft canister, Lander, De-orbit Motor and Parachute Assembly for ground operations assembly, service, and capsule/spacecraft integration.
- Ship flight equipment from Capsule Contractor Facility to KSC and remote test sites.
- Physically and environmentally protect flight equipment and personnel during shipment and ground operations.
- Avoid contamination of clean rooms.
- Protect both flight equipment and personnel from the hazards imposed by pyrotechnic and propellant handling, shock, and vibration, static electric discharge and possible mishandling.
- Provide a precision vertical load moving device to allow gradual mating of the Capsule to adapter and Capsule to Spacecraft.
- Operate within the environmental constraints imposed by McDonnell Report E191. Mobility per MIL-M-8990D, AHSE/human interfaces per MIL-A-8421B.

- AHSE utilized for physical handling operations will be designed to 4 times static handling loads and static tested to 2 times handling load.
- Load the Terminal Propulsion Subsystem (TPS) and Reaction Control Subsystem (RCS) tanks with propellants and pressurants within ± 1% by weight.
- Remove contaminants and toxic vapors from the capsule subsystems and OSE.
- Maintain a positive gas pad on the canister during shipping and storage.
- Provide gas for leakage and functional testing.
- Dispose of toxic and explosive liquids and vapors, and protect both flight equipment and personnel from hazards resulting from high pressure gas and toxic or corrosive fluids.
- Display parameters associated with the loading operations.

Figure 8.1-1

8-4-2
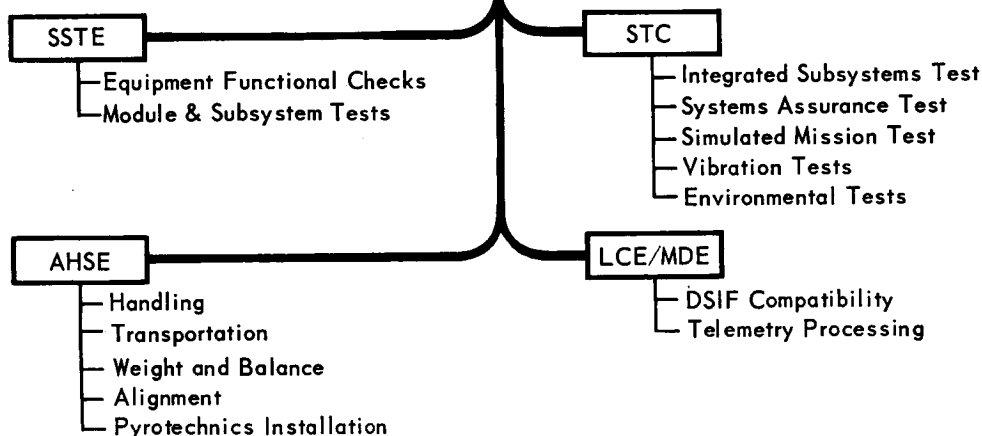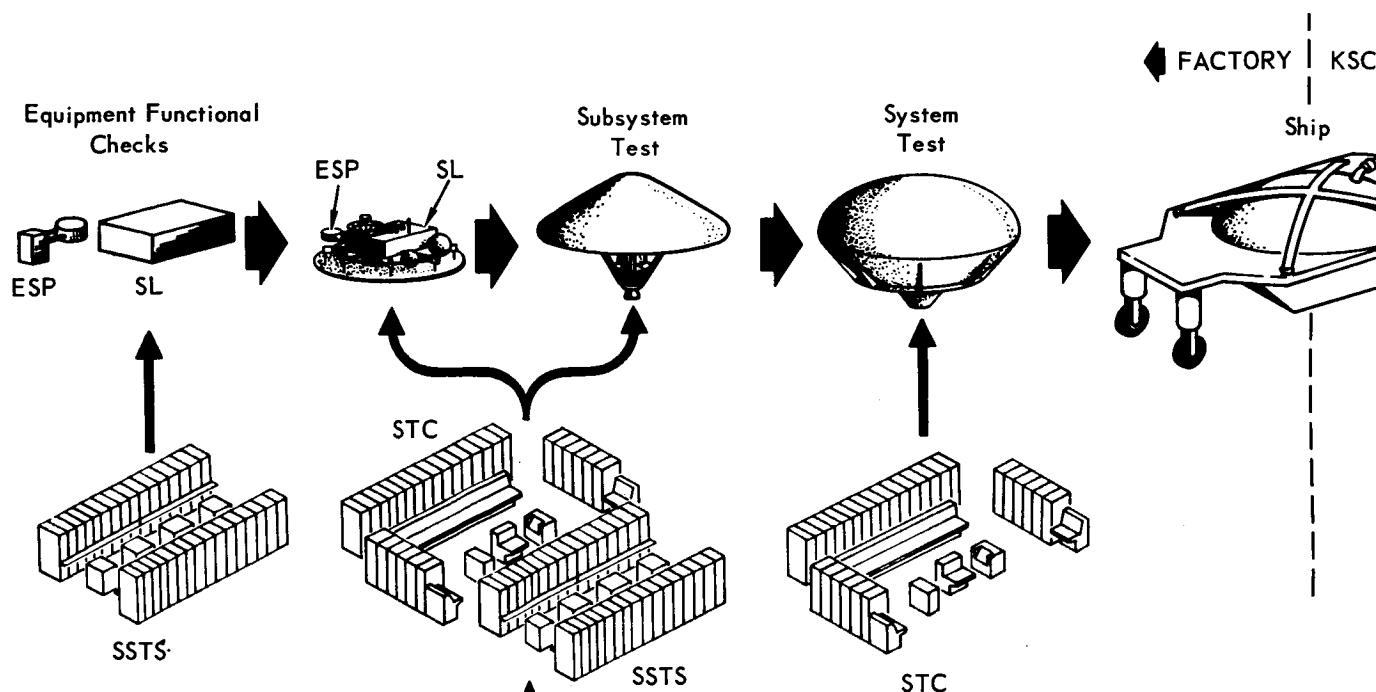
Figure 8.2-1

LEGEND
SSTE — Subsystem Test Equipment
STC — System Test Complex Equipment
LCE — Launch Complex Equipment
SSTS — Subsystem Test Sets

SSTE
—Equipment Functional Checks
—Module & Subsystem Tests

STC
— Integrated Subsystems Test
— Systems Assurance Test
— Simulated Mission Test
— Vibration Tests
— Environmental Tests

AHSE
— Handling
— Transportation
— Weight and Balance
— Alignment
— Pyrotechnics Installation

LCE/MDE
— DSIF Compatibility
— Telemetry Processing

8-5 −(

Spacecraft
Checkout
Facility

Explosive
Safe
Facility

Pad
39

Deep
Space
Network

STC

MDE
— DSIF Compatibility
— Countdown
— Cruise Monitor
— Inflight Checkout
— Descent Monitor

STC
— CB Systems Assurance Tests
— PV Systems Assurance Tests
— PV Simulated Mission
— SV Simulated Mission (J Fact)
— Post Sterilization CB Assurance
— PV System Confidence
— Final PV System Assurance
— PV System Verification
— PV/LV Composite Tests
— Countdown Demonstration
— Countdown

SSTE
— Contingency

LCE
— CBS System Test Support—SCF, ESF, PAD

MDE
— DSIF Compatibility
— Countdown

SCME
— CB System Tests

AHSE
— Handling/Transportation
— Servicing
— Pyro & Rocket Installation

Bus Telemetry and the Deep Space Instrumentation Facility (DSIF) at KSC, and to perform telemetry processing.

Spacecraft Mounted Capsule Bus Support Equipment OSE (SCME) - Used at the Spacecraft contractor's plant for subsystem testing of the CB hardware installed in the Spacecraft, and in the STC for integrated tests.

Assembly, Handling, Shipping, and Servicing Equipment (AHSE) - Used for transportation and handling of the Capsule Bus and for weight and balance, alignment, and rigging of structure and mechanical subsystems. Includes propellant and gas servicing equipment used at KSC.

The design characteristics of each of the preceding OSE categories will be described in the sections that follow:

8.3 SYSTEM TEST COMPLEX

8.3.1 Configuration and Usage - The Capsule Bus System Test Complex (STC) equipment consists of approximately 40 cabinets of system level test equipment. Addition of the STC equipment for SLS and ESP is expected to bring this total to 65 STC cabinets. The major elements of the CB STC include:

o **STC Subsystem Consoles** - Six sitdown consoles, each with a CRT for data display, a keyboard for addressing the Computer Data System (CDS), and critical hardline displays and commands.

o **Computer Data System (CDS)** - A high speed, general purpose computer with multiple memory blocks and expandable I/O capability that centrally controls the entire STC.

o **CDS Peripheral and Interface Equipment** - Tape transports, line printers, and card readers used to record data and provide inputs to the computer.

o **Test Director's Console** - A sitdown console used for executive control of CB subsystems testing in the STC. This console enables the other consoles for single or combined subsystems testing, and contains a CRT display plus critical parameter displays.

o **STC Required Mission Dependent Equipment (MDE)** - An exact duplicate of the MDE equipment and software used at the DSIF stations to detect and decode the CB downlink data, and to generate the uplink commands that are required during the mission.

o **STC Required Mission Independent Equipment (MIE)** - An exact duplicate of the Telemetry and Command Processor (TCP) computer, used at the DSIF's.

o **Ground Data Transmission System (GDTS)** - A digital transmission system used for transmission of TCM parameters and ground test data and commands between the STC and the Capsule Bus at remote locations.

o **Simulators** - Spacecraft, ESP, SLS, and DSIF interface simulation and control equipment required for system level testing and compatibility demonstration.

o **Special Purpose STC Equipment** - Timing and distribution, closed circuit TV (CCTV) intercom, complex cabling, and other specialized equipment required to complete the STC equipment.

The general arrangement of the Capsule Bus System Test Equipment is illustrated by Figure 8.3-1. After completion of Capsule Bus testing at the CB factory, the two sets of STC equipment are transported to KSC and installed in the Capsule

CAPSULE BUS SYSTEM TEST COMPLEX EQUIPMENT
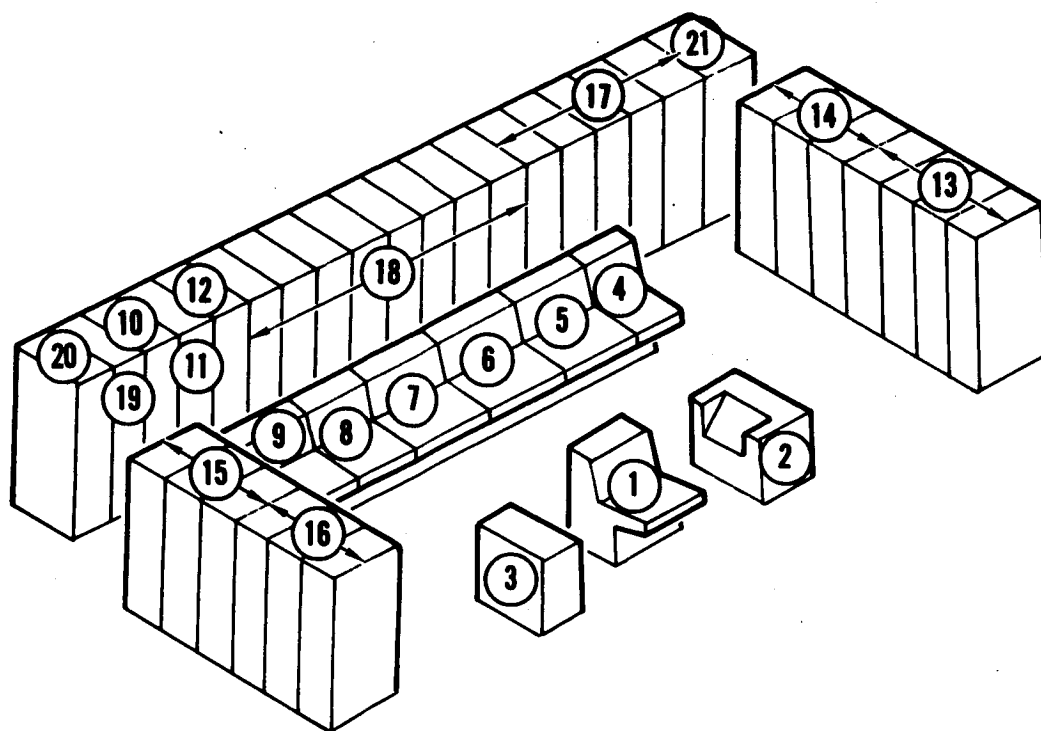
ITEM	TITLE
1	Test Director's Console
2	High Speed Line Printer
3	X-Y Plotter
4	TCM Console
5	Sequencer and Pyrotechnics Console
6	Radar Console
7	Guidance and Control Console
8	Propulsion and Thermal Control Console
9	Power and Distribution Console
10	Timing Distribution and Data Conversion Unit
11	Intercom, P.A. Access, Telephone
12	SLS and ESP Simulators
13	TCP Computer
14	TCP Peripheral Equipment
15	Magnetic Tape Recorders
16	Strip Chart Recorders
17	CDS Computer
18	CDS Computer Peripheral Equipment
19	Ground Data Transmission System
20	Spacecraft Simulator
21	CB MDE

contractor's control room, in addition to one STC previously moved to KSC with the Proof Test Model. The control room STC at KSC supports the periodic checkout of the two CB in storage (backup) in addition to the two CB undergoing scheduled pre-launch operations.

8.3.2 **Design Requirements and Constraints** - The System Test Complex (STC) design complies with the STC requirements specified in Figure 8.1-1, and provides a solution to the following OSE problems:

   a. <u>Data Transmission Through the Sterile Barrier</u> - The System Test Complex (STC) is designed to conduct integrated system level testing without the Subsystem Test Sets (SSTS), using only the flight telemetry data, the in-flight checkout and monitor system, and selected critical parameters that are brought through the sterile barrier via the Spacecraft Umbilical and an OSE Umbilical on the canister. The SSTS test connectors used for sub-system test prior to canister installation do not duplicate the flight telemetry umbilical data, which is the primary source of test data used by the subsystem test consoles in the STC. This concept provides a clean functional and physical interface between the Subsystem Test Consoles and the SSTS.

   b. <u>Integrated Control Room Operations</u> - The CB OSE packaging concept provides functional separation of the Subsystem Test Consoles from the Subsystem Test Sets (SSTS). This design feature, coupled with elimination of the scheduled use of SSTS at KSC, greatly reduces the total quantity of equipment and floor space required, and reduces congestion in the control room. These are significant factors in integrated operations and facility requirements at KSC.

   c. <u>STC Mobility</u> - The functional independence provided by the separate SSTS and STC concept reduces the total quantity of equipment to transport to KSC and thereby improves the capability for rapid transport and setup of the STC at KSC. Pre-cabling of control room STC, simplified cabinet connections, and fixed data links are used to further facilitate STC mobility.

8.3.3 **Operational Characteristics** - In operation, subsystem test engineers at the System Test Consoles select automatic test sequences or manual operations on the CRT keyboard. Response data is displayed on a Cathode Ray Tube (CRT) that can display up to 32 lines of parameters or computer outputted information in engineering units or English language. The CRT also is capable of plotting graphical data. An out-of-limits condition is indicated by a blinking of the affected parameters

displayed on the CRT, plus a CRT display of the results of the OSE self-check. For critical parameters, an audio-visual alarm is also activated. A typical system test console is illustrated in Figure 8.3-2. Test operations may be conducted on one or more subsystems simultaneously, as enabled by the test conductor. The high speed line printer at the Test Conductor's Console provides a permanent record of all test data required for flight acceptance. Fig. 8.3-3 is a block diagram of the STC.

Computer Data System - The Computer Data System (CDS) is a high speed general purpose computer used in the System Test Complex to perform automatic test sequencing, parameter limit evaluation, alarm monitoring, data suppression, and OSE self-check. The computer also is used to time-tag data and to drive a high speed line printer and teletypewriter. In the manual mode the CDS provides backup capability for fault isolation, program debugging, and program changes. The CDS computer in the STC should have the capability possessed by third generation computers, such as the Scientific Data Systems Sigma 5 GE 645, or IBM 360-67, in order to meet automation requirements and provide maximum potential for program growth and future missions.

The Computer Data System consists of the following major elements, as illustrated in Figure 8.3-4.

o   Central Processor Unit (CPU)

o   Core Memory

o   Multiplexer Input/Output Unit

o   Input/Output Device Controllers

o   CDS Peripheral Group

STC Required Mission Independent (MIE) and Mission Dependent Equipment (MDE)
In addition to the STC computer data system used for test automation, the STC contains an identical duplicate of the Mission Independent Equipment (MIE), Telemetry Command Processor (TCP) computer and Mission Dependent Equipment (MDE) that is used in the DSN. The MDE and MIE are used during checkout of the Capsule Bus, SLS, and ESP radio telemetry and command system, and DSIF compatibility tests. Use of the same model computer for the CDS and MIE functions offers potential for time sharing, software commonality, and reduced hardware quantity. Computer selection will be dependent on the type of Mission Independent computers used in the DSN for the VOYAGER program. The SDS 920 computers currently in use in the DSN will require supplementary computers to process the MFSK telemetry proposed for the SLS, and to accommodate the total load associated with simultaneous support of dual Capsule Lander/SLS operation.

8-10

TYPICAL STC CONSOLE

Figure 8.3-2 Typical STC Console showing: Hardlined Analog Meters, Discrete Light Indicators, Control Switches, Voice Communications, Alpha-Numeric Cathode Ray Tube Display, Keyboard

CAPSULE BUS SYSTEM TEST COMPLEX (STC)
BLOCK DIAGRAM

Notes:

- ←——→ = Analog Data
- ←——→ (P) = Parallel Digital Data
- ←——→ (S) = Serial Digital Data
- ←——→ = Other (as indicated)

△1 Not Used at Launch Pad

△2 Communications Controller
Out →Test Data Display
In ← Subsystem and STC Test Log
Information, Data Requests,
Manual Commands.

Figure 8.3-3

8-12-1

(P) Telemetry MDE

(P) Data Switch (P)

(P) Telemetry and Command Processor (TCP)

MDE Software

Tape Reader   Tape Punch   I/O Type-writer   Magnetic Tape Recorder Group

Tape Recorder Group

Capsule Bus Data from Spacecraft Ground Station During Integrated Test

Command MDE (P)

Timing Dist System   (P) Time Code Translator

(P) Data and ID   Commands

SLS in Flight C/O and Cruise Mode Data to SLS Contractor

(P) CDS I/O Control and Storage Devices (P)

(P) CDS Multiplexer Input/Output Unit (MIOP)

Computer Data System (CDS) Memory

(P) Direct I/O CDS Central Processor Unit (CPU) Interrupt System

32 Lines   D/A Converters   D/A Converter Controller   CDS I/O Controller

Real Time Test Data, all Test Log Data, STC Status

Hazard Alarms, Critical Test Mode/Sequence Commands

CDS I/O Controller

(P) Line Printer

Magnetic Tape Transport   Magnetic Tape Controller   CDS I/O Controller

(P) Keyboard and A/N CRT Display

Test Directors Console

Data Conversion Unit   CDS I/O Controller   CDS I/O Controller   Communications Controller   ⚠2

(S)

Card Punch   CDS I/O Controller   CDS I/O Controller   Rapid Access Data File (Disc)

Card Reader   CDS I/O Controller   CDS I/O Controller   X–Y Plotter

Status Signals; Mode Sequence Control

CDS Keyboard Printer   CDS I/O Controller   CDS I/O Control and Storage Devices (S)

Status Display, Data Display, Mode/Sequence Status

Manual Control Inhibit

Hazard and Emergency Alarms

Bi-Level (S)   Bi-Level (S)   Bi-Level (S)   Bi-Level (S)   Bi-Level (S)   Bi-Level (S)   Bi-Level

Keyboard and A/N CRT Display
Telecommunications, Instrumentation and Communications Console

Keyboard and A/N CRT Display
Sequential and Pyro Console

Keyboard and A/N CRT Display
Guidance Sensor (Radar) Console

Keyboard and A/N CRT Display
Guidance and Control Console

Keyboard and A/N CRT Display
Propulsion and Thermal Control Console

Keyboard and A/N CRT Display
Power and Distribution Console

8-12-2

COMPUTER DATA SYSTEM AND PERIPHERAL GROUP

Line Printer

Magnetic Tape Recorder Group

Central Processor Unit and Core Memory

Multiplexer Input/Output Unit

Processor Control

Rapid Access Data Storage

Keyboard Printer

Card Reader

Card Punch

Figure 8.3—4

Ground Data Transmission - The Ground Data Transmission System (GDTS) is a digital link consisting of two terminals, connected by an A2A wide band coax cable and voice grade telephone lines. Use of a Bose-Chaudhuri error control encoding/decoding system provides extremely low error probability ground test command transmission over long distances via relatively inexpensive telephone lines. The low error coding technique contributes significantly to mission success by reducing the possibility of erroneous test command transmission. The Bose-Chaudhuri system employs closed loop verification of the transmitted command prior to command execution. Figure 8.3-5 is a functional block diagram of the GDTS command link. The GDTS launch pad interfaces are described under Launch Complex Equipment (LCE) below.

8.4 LAUNCH COMPLEX EQUIPMENT (LCE)

8.4.1 Configuration and Usage - Launch Complex Equipment (LCE) provides the capability to condition the Capsule Bus for launch, to control and monitor critical functions on the launch pad, to fault isolate to the OSE or CB level, and to conduct system assurance and prelaunch checkout on the launch pad. LCE is used at the launch pad, the Explosive Safe Facility (ESF), and the Launch Control Center (LCC). The LCE uses selected STC equipment to minimize duplication. LCE consists of the following equipment:
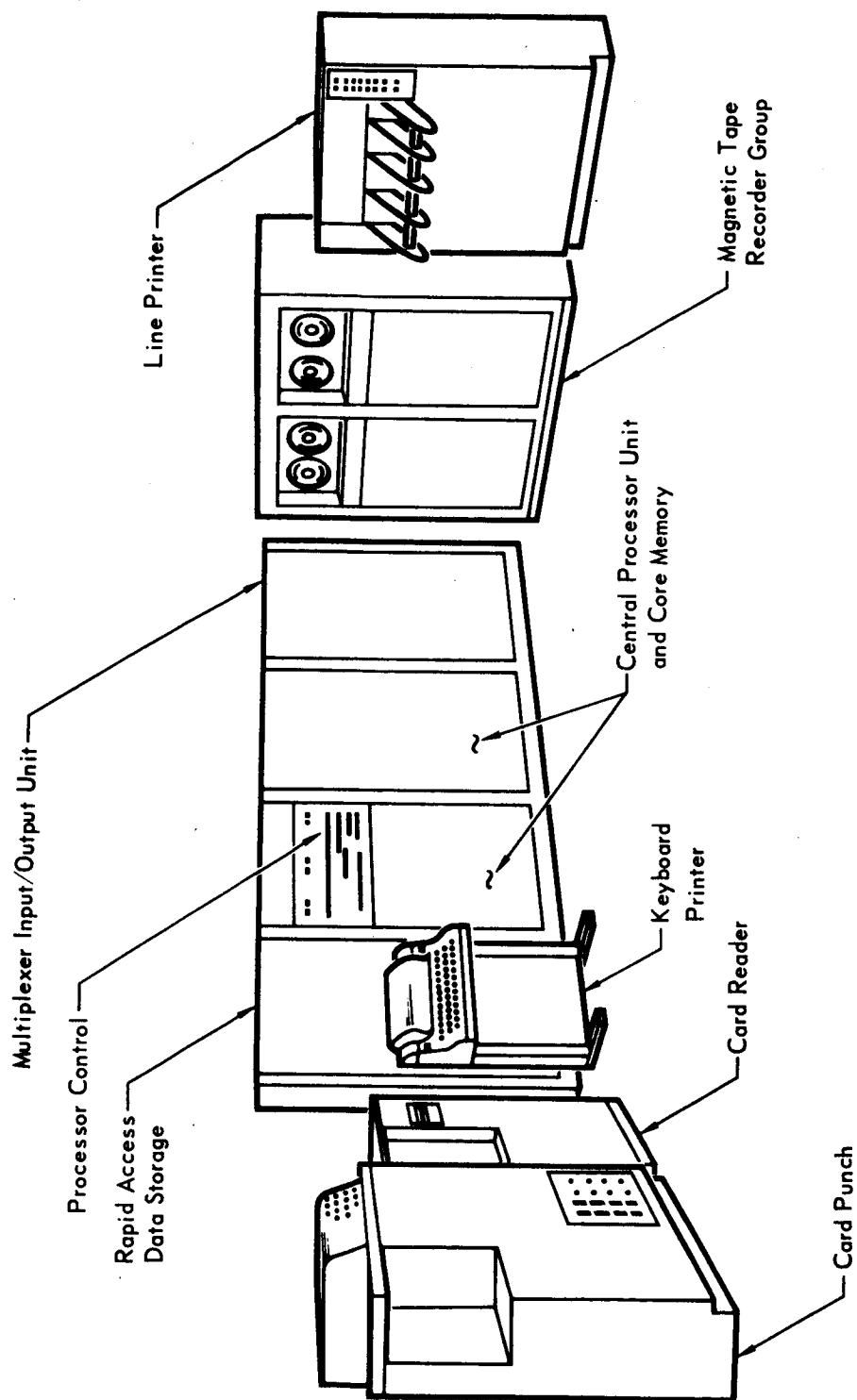
o   Ground Power and Distribution Equipment - A two-bay cabinet that provides automatic switching to facility backup power, emergency backup power in case of total facility power failure, and dc power to the CB. This equipment is located in the base of the Mobile Launcher (ML) and at the ESF.

o   Remote Simulation Equipment - Two cabinets of test signal generation equipment, located on the Mobile Launcher (ML), and used to provide stimuli for on-pad testing of the CB.

o   UHF Receiving System - Contains a UHF receiving system mounted on the ML which demodulates the CB UHF transmitter output (brought out the Spacecraft flyaway umbilical from a parasitic antenna in the canister) and transmits the TM data to the STC via the Ground Data Transmission System. Spectrum and power-output measurements are made from two cabinets of equipment on the Mobile Launcher.

o   CB Launch Monitor Console - A two-bay console located in the LCC, which has direct hardline access to the CB through the Spacecraft fly-away umbilical. CB, SLS and ESP subsystem status sent from the STC is also displayed on this console.

GROUND DATA TRANSMISSION SYSTEM, STC TO CB
FUNCTIONAL BLOCK DIAGRAM

STC TERMINAL UNIT

Self Test
Output Store
FM Demods
Input Store
Serial ID Format
Serial Encoder
Power Cont.
Blower

Transfer from TCP

Commands from TCP With ID

Commands and Self Test from CDS With ID

Input Interface and Storage

Data

Xfer

ID

Transfer from CDS

Manual Commands

Manual Execute

Output Transfers

Data and Sync. Format

Data

Xfer

Input Transfers

Xfer

Programmer

Parallel-to-Serial

Clock

2.4 KB Data

Bose-Chaudhuri Encoder

Retransmit

From GDTS

2.4 KB Data

Freq. Shift Keyer

Figure 8.3–5

8–15

CB TERMINAL UNIT

Mpx & A/D
Serial Format
FM Modulator
Self Test
Output Store
Sync & Decode
Serial Decode
Power Cont.
Blower

ce Grade
lephone Line

Self Test
Initiate to GDTS

To GDTS

Go No-Go

Self Test
Self Test Evaluate

Self Test Transfer

Data

ID Decode

Self Test

Decoded ID

Data

Transfer

To Remote Stimulation Equipment

Data

Transfer

Decoded ID

To UHF Receiving System

Data

FM Demod

Coded Data

Bose-Chaudhuri Decoder

Data

Serial-To-Parallel and Bit Counter

Transfer

Store

Data

To Ground Power and Distribution

Retransmit to GDTS

Sync. Recovery

Transfer

Store

Data

To Spacecraft Simulator

32 Bit Parallel to Serial Converter

Serial Data
Data Ready
Clock

To CB S & T

Transfer
Decoded ID

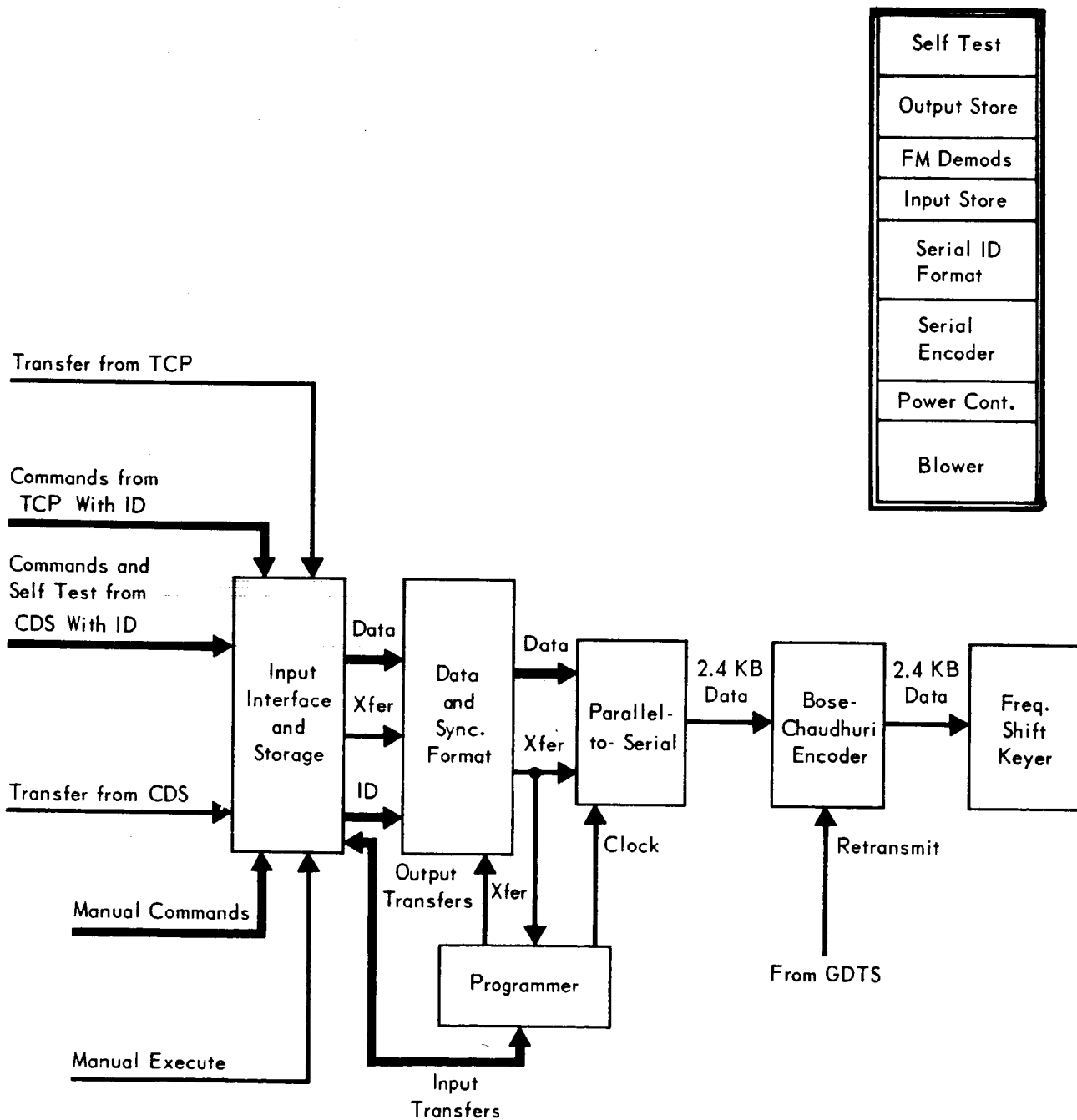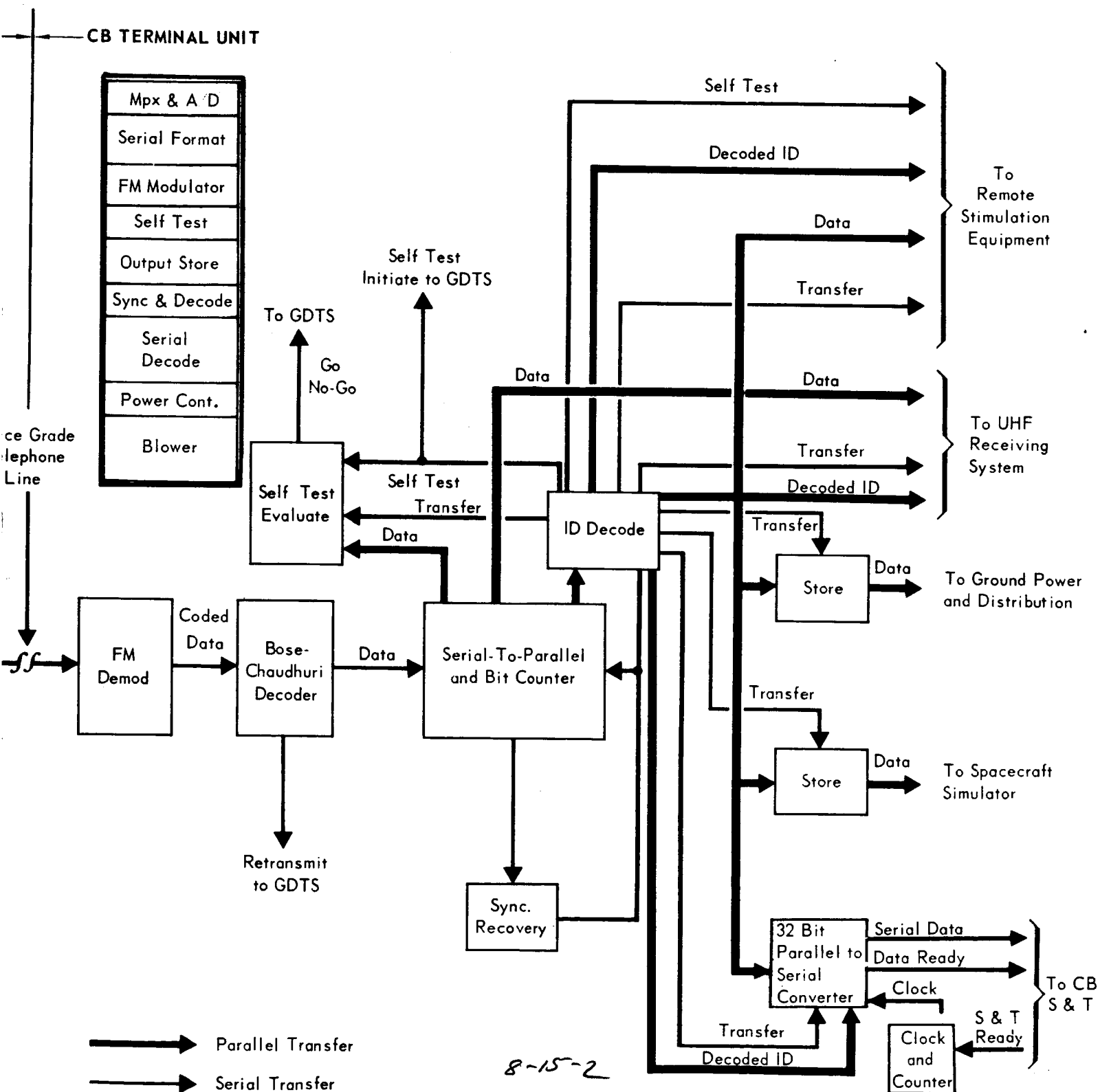Clock and Counter

S & T Ready

Parallel Transfer

Serial Transfer

8-15-2

o   <u>Hazard and Alarm Monitoring System</u> - The system consists of two cabinets
    of equipment in the ESF, plus warning panels and controls in the CB Launch
    Monitor Console at the LCC and in the Propellant Subsystem Console in
    the STC. The system provides hardline monitoring of propellant and gas
    pressures, pyrotechnic arming circuits, and leak detection sensors, and is
    interlocked with the Complex 39 warning system and an explosion proof
    power source.

o   <u>LCE Required STC Equipment</u> - Selected elements of the System Test Complex
    (STC), including the Computer Data System and Mission Dependent Equipment,
    required for on-pad testing of the CB. Test point access to the TCM is
    accomplished via the Spacecraft flyaway umbilical. The general arrange-
    ment of LCE is shown in Figure 8.4-1.

8.4.2 <u>Design Requirements and Constraints</u> - The Launch Complex Equipment (LCE) is
designed to meet the LCE requirements specified in Figure 8.1-1. Our approach em-
phasizes reliability and safety. LCE will be designed to a P_s allocation determined
by reliability and operations analyses. Computer monitoring of safety items or
critical parameters is backed up by redundant hardwired monitor and alarm circuitry.

8.4.3 <u>Operational Characteristics</u> - Operation of the LCE is from the ESF and the
STC during servicing, pyrotechnic checkout, de-orbit motor installation, and steri-
lization. Control shifts to the Launch Monitor Console in the LCC during launch
pad operations. The STC Computer Data System provides automatic alarm monitoring,
but approximately 20 critical CB parameters are hardlined to hardwired logic and
displays to give maximum reliability for control of unsafe or potentially catas-
trophic conditions. Elements of the LCE used during ESF and launch pad operations
include the UHF Receiving System, the Ground Power and Distribution Unit, the Re-
mote Stimulation Unit, and the Hazard Alarm System.

   <u>Launch Pad Data Link</u> - The Ground Data Transmission System (GDTS) used during
system level testing at the System Test Complex is also used with LCE at the ESF and
the launch pad as illustrated in Figure 8.4-2. Launch Complex Equipment (LCE) has
been designed to accomplish launch pad operations without connecting to the OSE umbilical.
This eliminates the requirement for an access door in the PV shroud, and reduces
hookup time on the pad. However, the Spacecraft flyaway umbilical must provide
approximately 50 pins for CB/SLS/ESP launch-critical signals and (2) RF coax connectors
for retransmission of radio frequency SLS MFSK and CB/ESP interleaved telemetry data.
This data is routed through the Spacecraft flyaway umbilical to a junction box on
the Mobile Launcher. At the junction box on the Mobile Launcher, CB data is

CB LAUNCH COMPLEX EQUIPMENT AT PAD 39
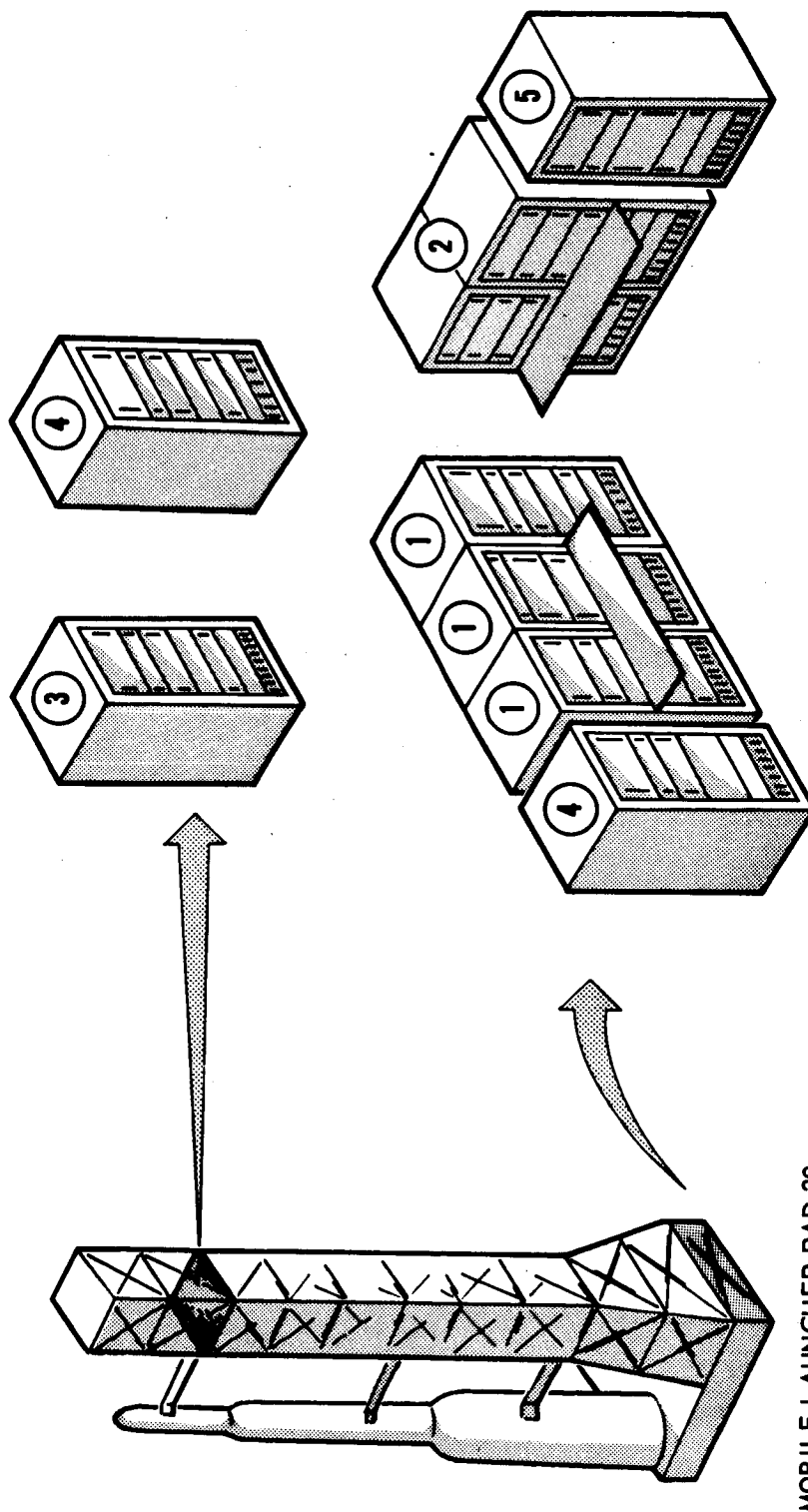
ITEM	TITLE
1	Ground Power & Distribution
2	Hazard Alarm System
3	UHF Receiving System
4	Ground Data Transmission System
5	Remote Stimulation System

MOBILE LAUNCHER PAD 39

OSE DATA LINKS AT KENNEDY SPACE CENTER

S/C Link – CB/SLS/ESP
In-flight C/O & Cruise Commutator Data

SLS RF to DSIF–71
Low Rate Transmitter Output
High Rate Transmitter Output
Command Receiver Input

DSIF–71

Junction Box

S/C Flyaway Umbilical

RF to DSIF-71
(Same as Pad)

Explosive Safe Facility

PV

CB

LCE

CB & ESP Data
to CB LCE

SLS Inflight c/o &
Cruise Commutator
Output

SLS Landed Data
(Video) Low & High Rate
and Command Receiver Input

(A2A Lines)

Hazard
Alarm,
Monitor &
Control

CB
LCE

S/C
LCE

Mobile
Launcher

(S/C Data Link)

CB TM Data and
LCE Monitor Data

(A2A lines) LCE Monitor
Functions and CB/SLS/EP
TM Data

LCE Control & CB/SLS
Command Functions

SLS Inflight C/O
and Cruise
Commutator via
S/C Data Link

LCE Control Functions
and CB/SL Command
Functions

Phonelines

CB/STC
Status
Data

Launch Monitor
Console (LCE)

Launch Control
Center

SLS Inflight c/o
and Cruise
Commutator via
S/C Data Link

S/C
Control
Room

CB
Control
Room

STC

PV

CB

SCF

Figure 8.4–2

8–18

split into three separate data trains, as shown in the LCE block diagram, Figure 8.4-3, and described below:

a. Data from the CB UHF and SLS landed TM is transmitted by A2A landline (GDTS) to the Capsule Bus System Test Complex. An alternate RF data path for the SLS is also provided, using parasitic antennas to provide an RF link between the SLS and DSIF.

b. The CB and SLS critical functions are analog hardlined to the CB/SLS Launch Control Equipment at Launch Control Center.

c. The SLS inflight checkout and cruise commutator output, interleaved with Spacecraft data, is transmitted to the Spacecraft contractor's ground station, where the SLS data is stripped out and retransmitted to the SLS System Test Complex Equipment in the Capsule Bus control room.

8.4.4 <u>Interfaces</u> - Primary interfaces between the LCE, STC, and MDE have been identified in previous Figures 8.4-2, Data Link and 8.4-3, functional block diagram.

8.5 MISSION DEPENDENT EQUIPMENT (MDE)

8.5.1 <u>Configuration and Usage</u> - The Capsule Bus MDE consists of CB equipment and computer software required to support telemetry processing and provide data interface compatibility in the Deep Space Instrumentation Facility (DSIF) and the Space Flight Operations Facility (SFOF) at Pasadena, as summarized below.

o <u>Data Demultiplexing Equipment</u> - Used at the Deep Space Instrumentation Facilities (DSIF's) to process the CB/ESP telemetry data from the S/C Mission Dependent Equipment to a level compatible with the capabilities of the existing DSIF Telemetry and Command Processor (TCP) computer.

o <u>CB Command Equipment</u> - Used at the DSIF's and the Space Flight Operations Facility (SFOF) for display of Capsule Bus TM data required for analysis of systems status and flight path.

o <u>Telemetry Command Processor (TCP) Software</u> - Used to program the TCP computer for decommutation of the TM data from the TM pre-processor. This software also programs the computer for acceptance and verification of commands sent from the SFOF, and addresses the commands to the CB Command Equipment.

o <u>CB TCM Simulator</u> - Used at the DSIF's to simulate the CB TM and Command System during pre-mission compatibility testing of the entire DSN with the CB TCM system.
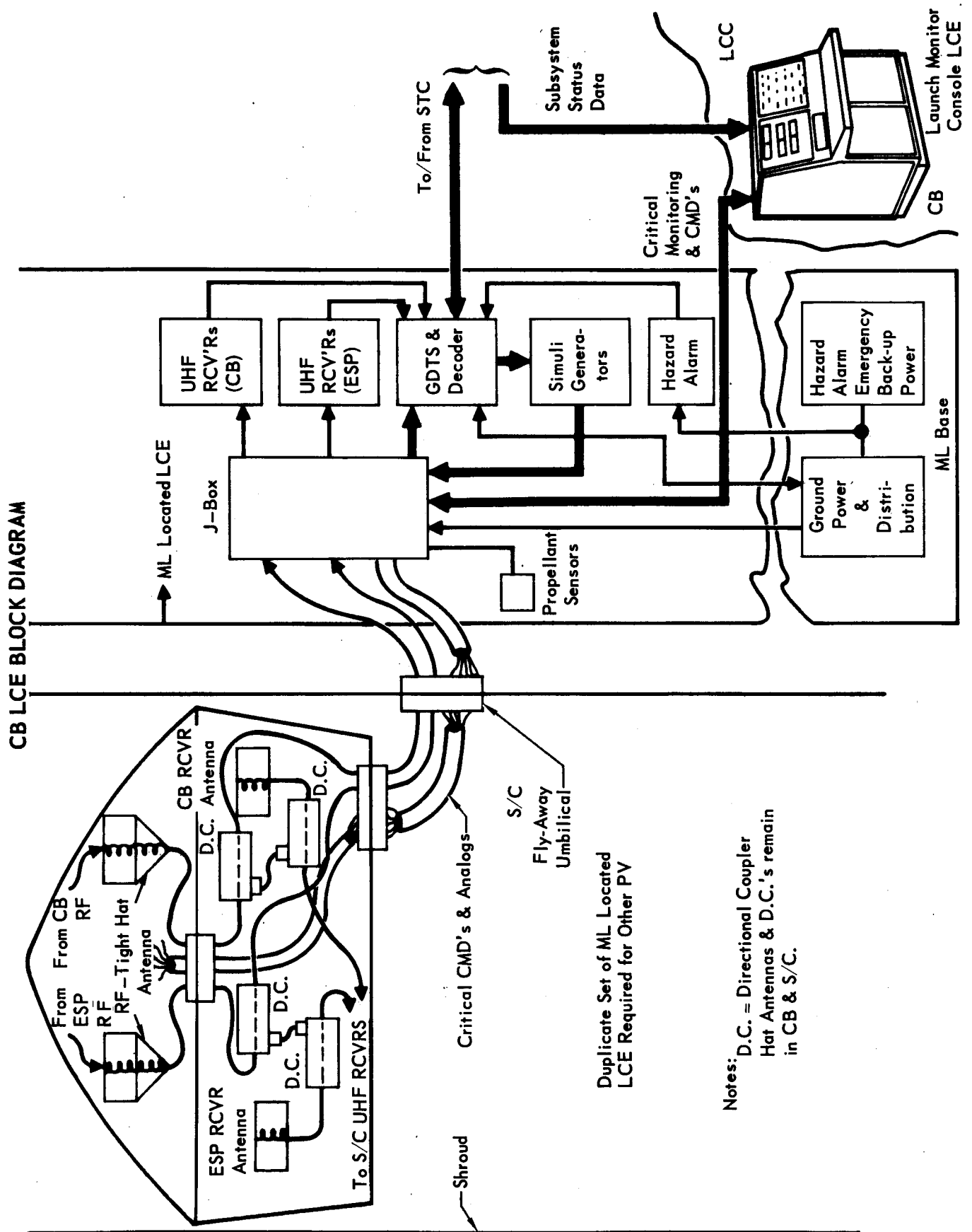
8-19

CB LCE BLOCK DIAGRAM

Notes: D.C. = Directional Coupler
Hat Antennas & D.C.'s remain
in CB & S/C.

Figure 8.4-3

8-20

8.5.2 <u>Design Requirements and Constraints</u> - The Mission Dependent Equipment is
designed to comply with the MDE requirements specified in Figure 8.1-1. The MDE
design approach is significantly influenced by the load which the dual CB/SLS/ESP/
Spacecraft places upon the existing TCP computers (SDS 920) in the DSIF. Use of
a Data Demultiplexer reduces the load on these computers by demultiplexing and de-
interleaving the real time and delayed time CB and ESP data, prior to TCP decom-
mutation and data distribution. A study of TCP computer processing, and of the
load imposed on the DSIF facilities, is provided in Supporting Data, Volume II,
Part D, Section 10.

8.5.3 <u>Operational Description</u> -

    <u>Operational Utilization of MDE at the Deep Space Instrumentation Facility (DSIF)</u>
Interleaved CB/ESP data and bit sync signals are obtained from the output of the
Spacecraft MDE. These signals are processed by the CB Data Demultiplexing equip-
ment and majority voting performed to derive the best quality data. These CB/ESP
data are de-interleaved and the CB and ESP data separated. The CB data is buffered
and formatted and read into the Telemetry Command Processor (TCP),which performs
decommutation, error detection and correction and processes the data for entry
into the station communications processor. This latter unit processes the data
for transmission over the high speed data link (HSDL) to the Space Flight Opera-
tions Facility (SFOF). Capsule Bus commands are transfered from the SFOF to the
DSIF within the Spacecraft command message structure. The CB command MDE inter-
faces with Spacecraft command MDE to validate CB commands as they are processed
for transmission over the S-band up-link.

    <u>Operational Utilization of MDE at the Space Flight Operation Facility (SFOF)</u> -
Capsule Bus data received via the HSDL from DSIF stations enters the SFOF communi-
cations processor where address recognition and message validation is accomplished.
The raw data from the communications processor is routed to the Telemetry Proces-
sing Station (TPS) for signal conditioning, decommutation and distribution to Dis-
play and Control Consoles. Decommutated data is fed to CB MDE quick-look displays
for early identification of CB performance and status and to the CB Engineering
Display MDE for use by the CB engineering analysis teams. These displays enable
presentation of engineering parameters and critical data, trend data, time-sequence
events and related mission parameters.

    The CB Control Console MDE provides a focal point for CB data collection and
dissemination. The data is routed to appropriate displays, selected data is
called up, and alarm and status functions are monitored.

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8.5.4 Interfaces - The major interfaces of Mission Dependent Equipment at the DSIF and SFOF are shown in Figure 8.5-1.

8.6 SUBSYSTEM LEVEL TEST EQUIPMENT

8.6.1 Configuration and Usage - Capsule Bus Subsystem Level Test Equipment consists of approximately 30 cabinets of equipment which provide complete test capability for all subsystems composing the Capsule Bus System. Flight Subsystems functions are grouped to minimize duplication of OSE and to provide the maximum utilization of common designs. The same Subsystem Test Set (SSTS) may be used for flight subsystem functional check, subsystems test during major module buildup and integration, subsystem tests in conjunction with the Systems Test Complex, and subsystem tests at KSC in the event of a contingency. The CB Subsystem Test Sets and the flight equipment they support are listed below:

Subsystem Test Set (SSTS)	CB Subsystem Supported
Guidance and Control	Guidance and Control
Electrical Power	Electrical Power
Propulsion	Reaction Control, Terminal Propulsion
Pyrotechnic	Pyrotechnic
Radar	Landing Radar, Radar Altimeter
Sequencer	Sequencer
Telecommunications	Antenna, Command, Data Storage, Radio, Telemetry
Thermal Control	Thermal Control

8.6.2 Design Requirements and Constraints - The Subsystem level test equipment is designed to comply with the SSTE requirements specified in Figure 8.1-1. The foremost aspect of these requirements is the need to establish an accurate repeatable test data base as the foundation for a continuous test history which will provide a reliable and accessible source of diagnostic and trend analysis data. The Subsystem level data must be readily correlated with system level test data acquired after canister installation.

8.6.3 Operational Description - Test sequencing, control, and monitoring are automated for Guidance and Control, Radar, Sequencer and Telecommunications Subsystems Test Sets on the basis of cost effectiveness and the subsystem's compatibility with high-speed, repeatable test programming. The repeatability and continuity which automation imparts to the CB test history is a significant contribution to mission success. Incorporation of an independent automatic processor in each of these test sets provides minimum flight subsystem operating time, maximum scheduling

SIMPLIFIED BLOCK DIAGRAM, CB MDE AT DSIF
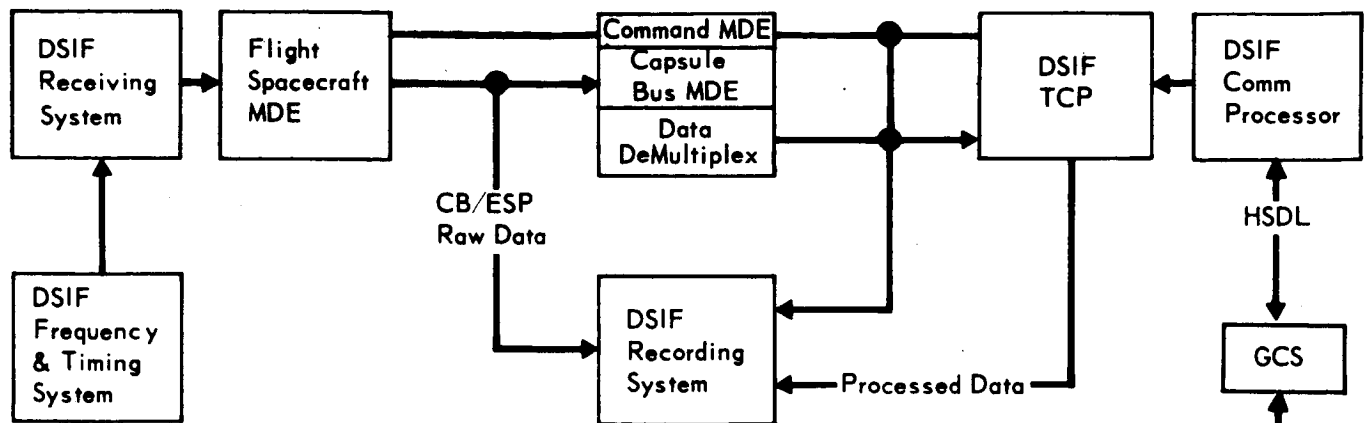
SIMPLIFIED BLOCK DIAGRAM, CB MDE AT SFOF
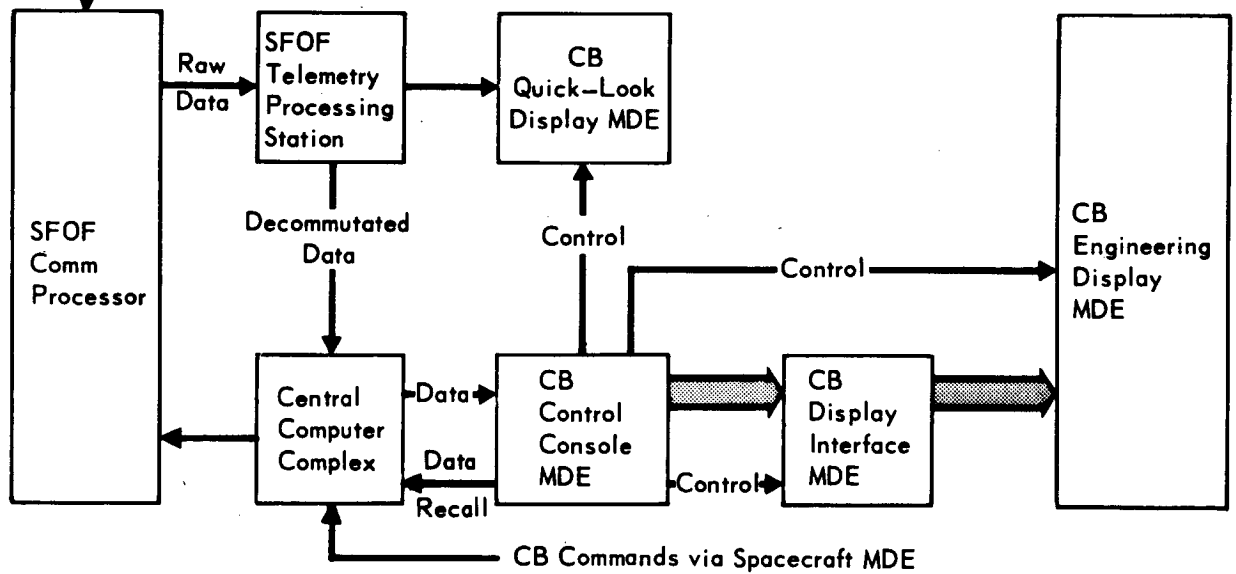
TCP = Telemetry Command Processor
HSDL = High Speed Data Link
GCS = Ground Communication System

flexibility, independent operation, and potential for future operation in a "satellite" mode under central computer control.

To minimize human error and retain the inherent accuracy of the analog data, extensive use is made of digital displays in the Subsystem Test Sets (SSTS). The SSTS provide stimuli, display, recording, time, loads, and alarm monitoring for the subsystem under test. Marginal performance testing is accomplished by programmed variation of the stimuli. Significant analogs or events are recorded on oscillographic recorders integral to the test sets.

Subsystem Test Sets (SSTS) typically consist of three functional sections, an automatic processor, an interface unit, and the basic test equipment. The subsystem under test is connected directly to the SSTS by analog hardlines. Control, power, and conditioning as required are supplied to the flight subsystem by the SSTS. Test sequence and control is provided by the stored program within the automatic processor. In addition to control, this processor monitors and compares subsystem responses to stored limits, outputs out-of-tolerance data to teleprinter, outputs all test data, time-tagged, to the paper tape punch for recording, permits test program modification by teletype or punched tape input and provides OSE self-test and fault isolation capability. Figure 8.6-1 is a block diagram of a typical SSTS.

8.6.4 <u>Interfaces</u> – The automated test sets are capable of interfacing with a general purpose digital computer for test sequence control or direction and data acquisition and display. This capability is not considered cost-effective for manual test sets. Simulators for the Spacecraft, Surface Laboratory System and Entry Science Package are provided for complete and independent subsystems and systems tests. Detailed descriptions of individual SSTE and simulator interfaces are discussed in Part D, Section 5.0.
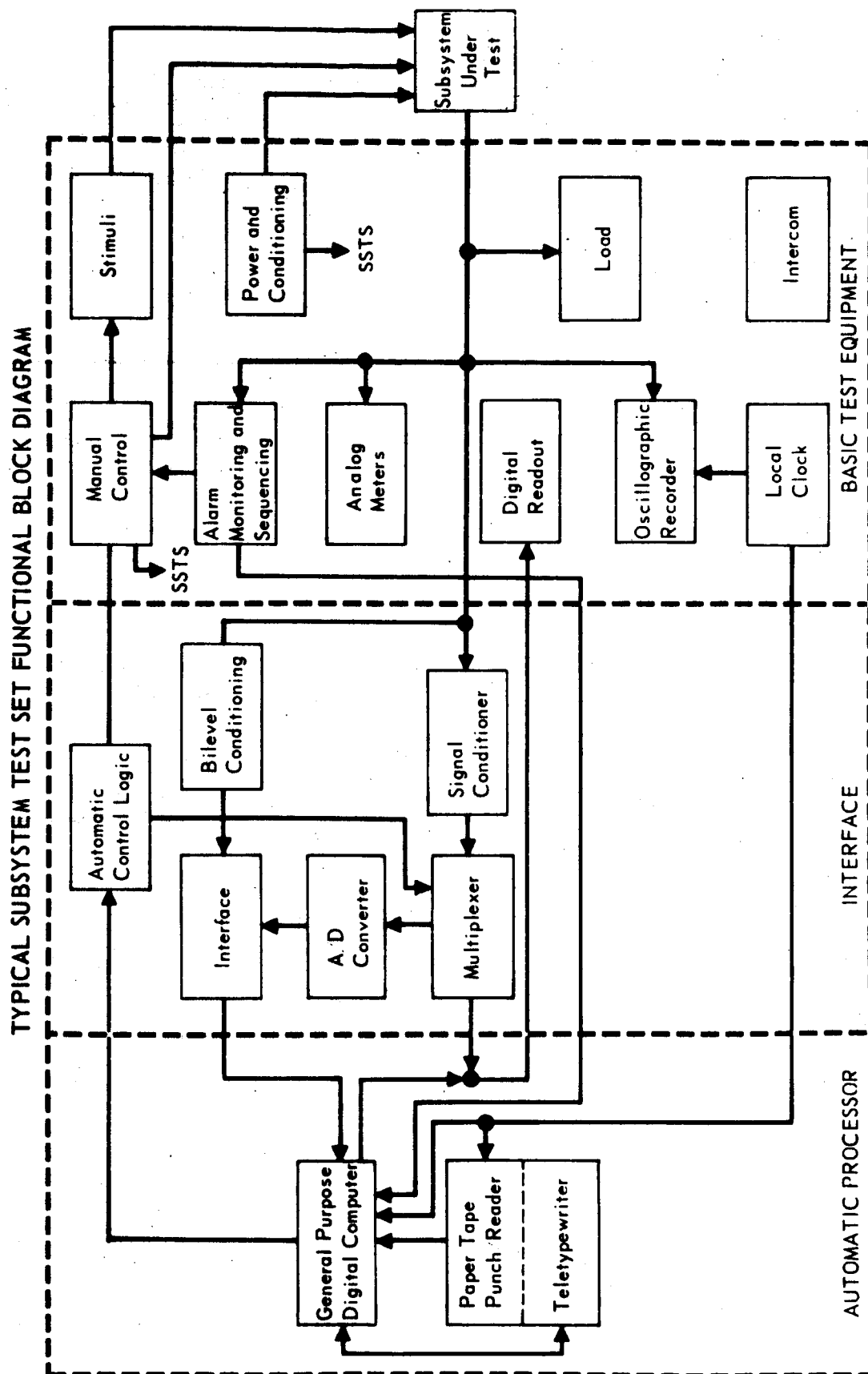
TYPICAL SUBSYSTEM TEST SET FUNCTIONAL BLOCK DIAGRAM

8.7 ASSEMBLY, HANDLING, SHIPPING, AND SERVICING EQUIPMENT (AHSE)

8.7.1 <u>Handling and Shipping Equipment-Configuration and Usage</u> - Capsule Bus handling and shipping equipment is designed to assemble, weigh, balance, align and ship the Capsule Bus System and components from factory through capsule/spacecraft integration. Approximately 25 items of handling and shipping AHSE have been defined, including the following major items:

a. Flight Capsule Transporter

b. Capsule Bus Handling Fixture

c. Capsule Bus Handling Dolly

d. Capsule/Canister Assembly and Checkout Stand

e. De-orbit Motor Installation Fixture

f. Forward Canister Work Stand

g. Capsule Bus Work Stand

h. Capsule Bus Weight and Balance Adapter

i. Lander Installation Fixture

The use of assembly, handling and shipping equipment at the CB contractor's factory is shown in Figure 8.7-1. Figure 8.7-2 illustrates handling and ground operations at KSC. Ground handling equipment used only at the CB contractor's factory primarily for factory or developmental testing is classified as manufacturing tooling or laboratory test equipment, and will be defined in detail during Phase C studies.

8.7.2 <u>Design Requirements and Constraints</u> - The handling and shipping equipment is designed to comply with the AHSE requirements specified in Figure 8.1-1. The design concept for handling and shipping equipment is influenced primarily by transportation, safety and sterilization constraints, in conjunction with the grouping of handling operations to meet schedule requirements with the minimum equipment quantity. The physical size (approximately 20 ft. dia. x 12 ft. high) of the canistered capsule severely limits transportation methods. The B-377-SG (Super Guppy) airplane is capable of encompassing the canistered capsule and has been selected as the primary transportation mode. Because only one such aircraft exists, barge transportation has been selected as a feasible backup mode. Helicopter lift from the factory to the barge avoids conflict with traffic ordinances and local loading facility constraints.

8.7.3 <u>Descriptions of Major Handling and Shipping Equipment</u> - The Flight Capsule Transporter is designed for either aircraft or barge transport, consists of a structural container for the Flight Capsule, plus running gear, and provides shock and vibration isolation. The use of integral structure simplifies handling,

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Capsule Bus
Handling Sling

Aeroshell

Capsule Bus
Adapter Fixture

Capsule Bus
Handling Fixture

Insert Aeroshell into
Capsule Bus Handling Fixture

Handling Fixture in
Erected Position

Capsule Bus
Removed from Fixture

Auxiliary Hoist Control

Fwd Section
Handling Sling

Fwd Section Canister

Capsule/Canister
Assembly &
Checkout Stand

Removal of Forward
Canister Section

Capsule/Canister Stand
in Erected Position

Class 100 Clean Room Operations

Air Transpo
Adapt

Auxiliary Hoist Control

Flight Capsule
Transporter

Canister
Handling
Sling

Load Cell &
Compression
Yoke

Canister Capsule
Weighing Operation
(Single Point)

Environmental
Chamber

Capsule Bus
Handling Dolly

Capsule Bus In
Shipping Condition

Aircro
Loac

Figure 8.7-1

Capsule Bus Insertion
into Handling Dolly

Weight and Balance
Operation

Forward Canister Section

Forward Section
Canister Stand

Capsule Bus/Canister
Integration

Flight Capsule
Transporter

Nose Open for Loading

B-377SG Aircraft

Loading Capsule/Transporter
for Air Shipment

Airport Ramp Operation

Capsule/Transporter
in B-377SG Aircraft

To KSC

8-27-2

Figure 8.7–2

Class 100 Clean Room Operations

Auxiliary Hoist Control
Fwd Section Handling Sling

Capsule Bus Handling Sling

Capsule Bus

Capsule Bus

Capsule Bus Adapter Fixture

Capsule Bus Handling Fixture

Ground Operations:

Disassembly
Propellant Service
Pyro Installation
Deorbit Motor Installation
Checkout
Re-assembly

Aft Canister Section

Capsule Canister Assembly & Checkout Stand

Removal of Capsule Bus from Canister

Capsule Canister Assembly and Checkout Stand

Forward Canister Section

Auxiliary Hoist Control
Load Cell & Compression Yoke

Forward Section Canister Stand

Canister Handling Sling

red Capsule
g Operation
Point)

Capsule Bus/Canister Integration

8-28-2

support, and disassembly for return shipment by common carrier. A controlled, clean environment is maintained within the Flight Capsule container by a dry GN_2 supply with a 1.0 psig positive pressure. Servicing provisions are included in the base plus a GN_2 supply for container replenishment and strut servicing.

The Capsule Bus Handling Fixture provides both positioning and retention capability for the Capsule Bus for final assembly, service and checkout in a Class 100 clean room. The fixture consists essentially of a rotatable capsule bus interface, a base, and an electro-mechanical drive assembly that provides the required rotational power. The fixture allows ground operations while the Capsule Bus is positioned with the axis horizontal, providing interfaces for the installation fixtures required for the lateral insertion of the Lander, De-orbit Motor and Parachute Assembly.

The Capsule/Canister Assembly and Checkout Stand is used to retain and position the aft canister for assembly, service, checkout, insertion of the Capsule Bus and integration with the forward canister. Intrafacility mobility is also provided. The Lander and De-orbit Motor Installation Fixtures are used for the lateral insertion into the Capsule Bus while it is retained in the Capsule Bus Handling Fixture with the "Z" axis horizontal. The fixtures provide for separate or coordinated adjustment required to align the Lander or De-orbit Motor for installation.

Five items of flight equipment will require precision alignment. The Lander and De-orbit Motor will be aligned optically with standard laboratory equipment. Special gages and fixtures will be required for the mechanical positioning of the UHF and Radar Antennas as well as the Inertial Measurement Units.

Precision mating will be accomplished by lowering the Capsule onto the Spacecraft (positioned with the "Z" axis vertical), utilizing the Canister Handling Sling and overhead crane with the Auxiliary Hoist Control providing the necessary critical control.

8.7.4 <u>Interfaces</u> – Handling and shipping equipment will interface with hard points on the Capsule Bus, Canister Sections, Lander, De-orbit Motor and Parachute Assembly, as well as well as with the following:

Facilities: Overhead Crane, Electrical Power, Weight and Balance Fixtures, Rotational Pedestals

Transport Carrier: B-377-SG aircraft pallet or barge

8.7.5 <u>Servicing Equipment-Configuration and Usage</u> – Capsule Bus Servicing Equipment consists of the equipment required to load the terminal propulsion and

reaction control subsystems with propellants and gases and to clean and maintain these subsystems. In addition, equipment for propellant disposal and canister pressurization is included in this category. Approximately 12 items of Servicing Eequipment have been defined, including the following major items:

     a. Propellant Loading Units

     b. Flush and Purge Units

     c. Propellant Disposal Systems

     d. GN_2/GHe Servicing Unit

     e. Canister Pressurization Unit

The use of the servicing equipment at the capsule bus contractor's facility and KSC is shown in Figures 8.7-3 and 8.7-4, respectively.

8.7.6 <u>Design Requirements and Constraints</u> - The Servicing Equipment is designed to comply with the AHSE requirements specified in Figure 8.1-1. The toxic and explosive characteristics of hypergolic propellants and high pressure gas systems impose a stringent requirement on servicing equipment to positively prevent damage to flight systems or facilities, to safeguard operating personnel, and to prevent the spread of contaminating vapors.

8.7.7 <u>Descriptions of Major Servicing Equipment</u> - All Servicing Equipment is manually operated and self-contained with automatic monitor and alarm for critical parameters. Fluid and gas supplies are contained in integral tanks or standard "K" bottles. Relief valves are used to limit pressures in all fluid lines and to protect pressure vessels and storage tanks. During operation all relief valves from propellant servicing equipment are vented to a closed disposal system. Hand valves are provided to bleed all pressurized lines and hoses. All equipment is designed to four times operating pressure and is proof tested to two times operating pressure. Hose terminals are keyed to prevent inadvertent interface with the wrong fitting.

The Propellant Loading Units are mobile, self-contained storage and transfer units designed for use at the ESF prior to sterilization. A GN_2 pressure transfer system is employed to load the propellants with an accuracy of $\pm1\%$, by weight, of the flight systems' tank capacity. The Propellant Loading Units contain direct pressure and quantity displays. Separate units supply Monomethyl Hydrazine (MMH) and Nitrogen Tetroxide (N_2O_4) for the Terminal Propulsion Subsystem and Hydrazine (N_2H_4) for the Reaction Control Subsystem. Propellant loading is accomplshed sequentially in the interest of safety. A typical Propellant Servicing Unit is illustrated in Figure 8.7-5.

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ST. LOUIS SERVICING EQUIPMENT UTILIZATION
ST. LOUIS TEST AREAS

SYSTEM

Helium Leak Detector — GHe Pressurization Unit

Propulsion Subsystem Test Console — GHe Pressurization Unit

Flush & Purge Unit (One Unit Used For All Subsystems)

Propulsion Subsystem Tool Set

Canister Pressurization Unit — Shipping Container & Canister Ref

Helium Leak Detector — Shipping Container & Canister Ref

SUBSYSTEM

Helium Leak Detector — GHe Pressurization Unit

Propulsion Subsystem Test Console — GHe Pressurization Unit

Flush & Purge Unit (One Unit Used For All Subsystems)

Propulsion Subsystem Tool Set

Canister Pressurization Unit — Canister Ref

EFC

Helium Leak Detector — GHe Pressurization Unit

Propulsion Subsystem Test Console — GHe Pressurization Unit

Propulsion Subsystem Tool Set

Canister Pressurization Unit — Shipping Container & Canister Ref

Helium Leak Detector — Shipping Container & Canister Ref

Figure 8.7-3

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INDUSTRIAL AREA SERVICING EQUIPMENT UTILIZATION

Propulsion Subsystem Test Console

Helium Leak Detector

GHe Pressurization Unit

Flush & Purge Unit
(One Unit Used for All Subsystems)

Helium Leak Detector

Canister Pressurization Unit

Shipping Container & Canister Ref
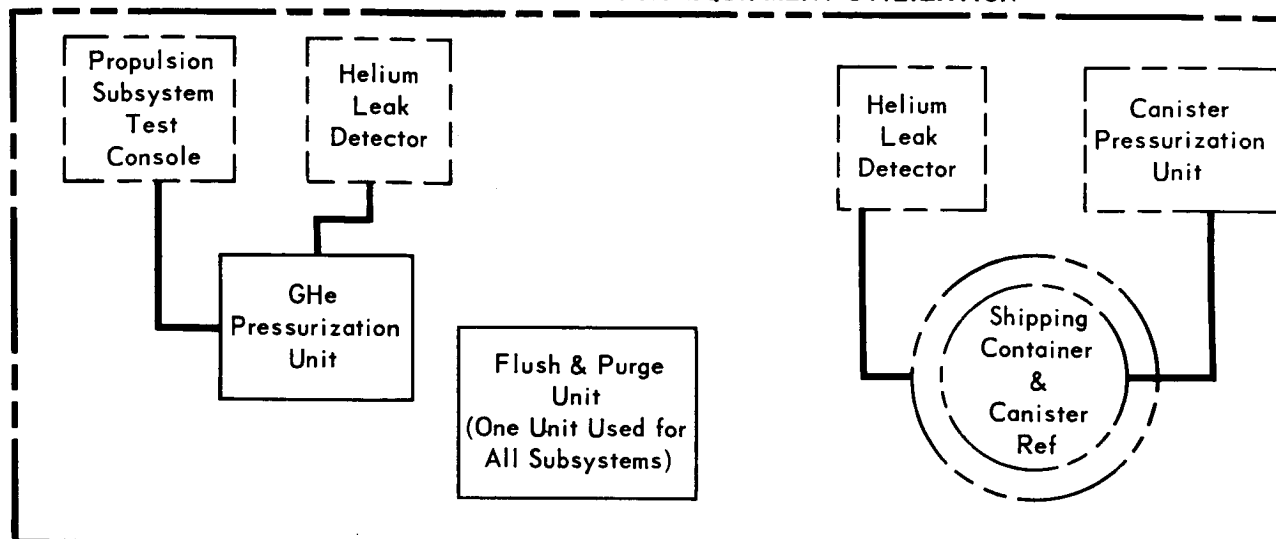
For Contingency Use
& Servicing OSE Post
Servicing Clean Up

Propellant Disposal System Vent Burner Stack

MMH Flush & Purge Unit

N₂H₄ Flush & Purge Unit

N₂O₄ Flush & Purge Unit

Personnel Safety Equipment (SCAPE Suits, Etc.) (Ref)

Fire Fighting Equipment (Ref)

Personnel Showers (Ref)

Eye Wash Basins (Ref)

GHe Pressurization Unit

Helium Pressurization Unit

Capsule Bus

Capsule Bus

To Servicing

Note: These Units are Used Sequentially and are Never in the ESF Simultaneously

Helium Leak Detector

TPS & RCS Leakage Test

To Final Canister Leak Test

Helium Leak Detector

Shipping Container & Canister Ref

ESF SERVICIN

Figure 8.7–4

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Propellant Purge & Disposal System

MMH Flush & Purge Unit

For Contingency Use Only

N₂O₄ Flush & Purge Unit

N₂H₄ Flush & Purge Unit

Capsule Bus

S/C

Hazard Alarm & Display Console (Ref)

Hazard Alarm (Ref)

Fire Fighting Equipment (Ref)

Personnel Safety Equipment (SCAPE Suits, etc) (Ref)

Eye Wash Basins (Ref)

Personnel Showers (Ref)

Liquid & Vapor Propellant Disposal System Terminal Box

Disposal System Plumbing

Liquid & Vapor Propellant Disposal System Terminal Box

Local Alarm (Ref)

Local Alarm

MMH Servicing Unit

Hazard Alarm & Monitor Console (Ref)

Hazard Alarm & Monitor Console (Ref)

N₂H₄ Servicing Unit

N₂O₄ Servicing Unit

Capsule Bus

Capsule Bus

Canister Pressurization Unit

Canister Pressurization Unit

Sterilization Oven

Storage Area

8-52-2

SERVICING UNIT – N_2O_4

SCHEMATIC

BLOCK DIAGRAM

The Propellant flush and purge is accomplished using freon MF and isopropanol as flushing and decontamination agents, and GN_2 pressure transfer. An integral sump tank is provided for containing contaminated flush fluid. Warm GN_2 is used to purge and dry the subsystem.

The Disposal System at the Explosive Safe Facility (ESF) provides for venting of gases and disposal of fluids during normal operation. A propane burner system prevents the venting of toxic gases or fluids to the atmosphere. At the launch pad and the ESF the Disposal System provides the capability for emergency deservice of propellants and an N_2 purge of explosive vapors which may be contained within the canister. The capsule flight propulsion systems have been designed to interface with the emergency deservice system through a burst diaphragm and connector installed at the canister moldline.

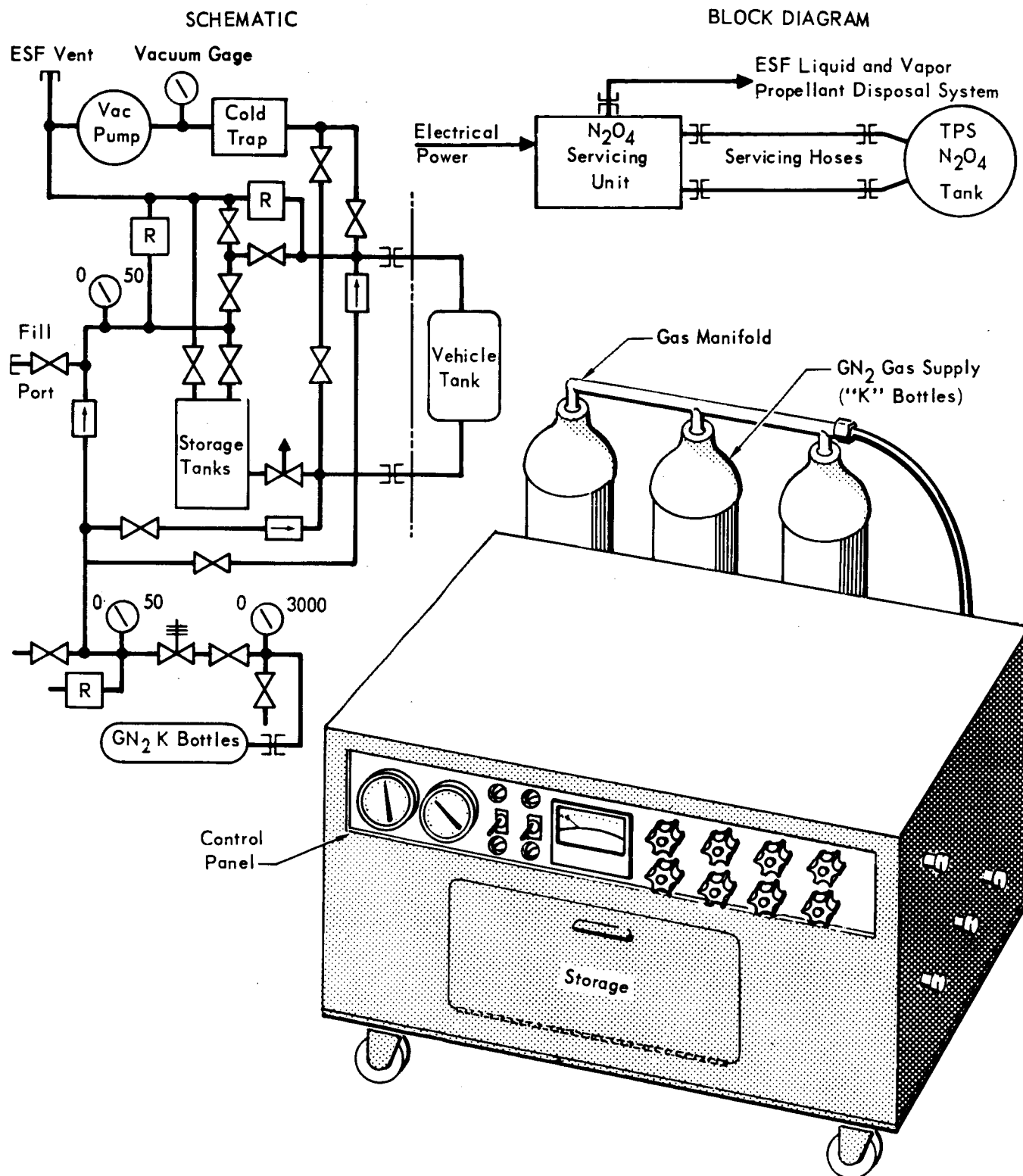Leak detection at the factory and the ESF prior to servicing is accomplished with a helium mass spectrometer (sniffer), using hand held probes and helium pressurized systems. The helium sniffers are also used in conjunction with the Canister Pressurization Unit (CPU) to detect canister leakage. The CPU and its nitrogen gas supply are connected to the canister during sterilization to provide sterile gas make-up during heating and cooling cycles. After servicing, detection of toxic or explosive propellant vapors is accomplished with the Hazard Warning Alarm system and vapor detection sensors.

Interfaces - Facility power is required for operation of the Servicing Equipment in addition to this interface between the flight subsystems. One possible interface problem has been identified. To provide emergency dump, disposal hoses or connectors must pass through the PV shroud, requiring an access door or fitting. An alternative solution would require the use of a fly-away umbilical. Further study of this interface is intended.

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8.8 SOFTWARE - The VOYAGER Capsule Bus System (CBS) requires an efficient and centralized, systems oriented control of the total CBS software program. We have outlined Capsule Bus, SLS, and ESP responsibilities and established a software development and packaging approach which will provide compatible software and maximum commonality of software programming and procedures. Within each contractor's area of responsibility we have established the following first tier of software packaging to provide effective control:

a. Support Software for Capsule Bus, Surface Laboratory and Entry Science Package Subsystem Test Sets (SSTS). Support software provides the basic tools for preparation of higher level subsystem software. Diagnostic and self-test routines, character conversion routines, and off-line or non-real-time tasks are examples of support software.

b. Operational Software for CB, SLS, and ESP SSTS. Operational software includes on-line routines, test programs for test sequence control, stimuli application,   measurement of responses, and executive routines and special processors.

c. Support Software for CB, SLS, and ESP Systems Test Complex (STC) (Similar to the SSTS Support Software).

d. Operational Software for CB, SLS, and ESP STC. This software includes programs for all systems tests and simulated missions.

e. Common STC/SSTS Support Software. Programs such as a configuration data file maintenance processor, test program preprocessor and test results processor may be common to both SSTS and STC, depending upon the computers selected, test language used and physical proximity of the computers.

f. MDE Software required for the Telemetry Command Processor (TCP) Computer used in the CB, SLS, and ESP System Test Complex and in the Deep Space Network for data processing.

Our software development program is shown in Figure 8.8-1. When the program is verified, it is released for use, with copies stored in the program library, and formal configuration control is initiated. An Integrated Systems Bench Test Unit (ISBTU) or similar development hardware is used for software debugging to assure software in advance of the scheduled use on the Proof Test Model, thus providing a program schedule contingency.

A detailed description of software management, development, test language, procedures, and documentation is provided in Part D, Section 8.

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TEST PROGRAM DEVELOPMENT AND MAINTENANCE

Customer/MDC Change Specification → OSE Configuration Modification

Test Requirements Document

Flight Equipment Specifications

Configuration Data File Maintenance Program

Trouble-Shooting Listing and Aids

OSE TRD

Review List and Errors; Correct

Test Language Programming

Test Listing and Error Notes

Test Program Preprocessor

Review for Errors and Correct

Test Program Tape

Executive Program

Test Results Listing

Checkout Computer

Test Director's Panel

Debugged Test Programs Will Be Retained At and Distributed From a Central Master Tape Library

Displays

Test Results

Test Results Processor

Program Checked on OSE/Subsystem Bench Test Unit

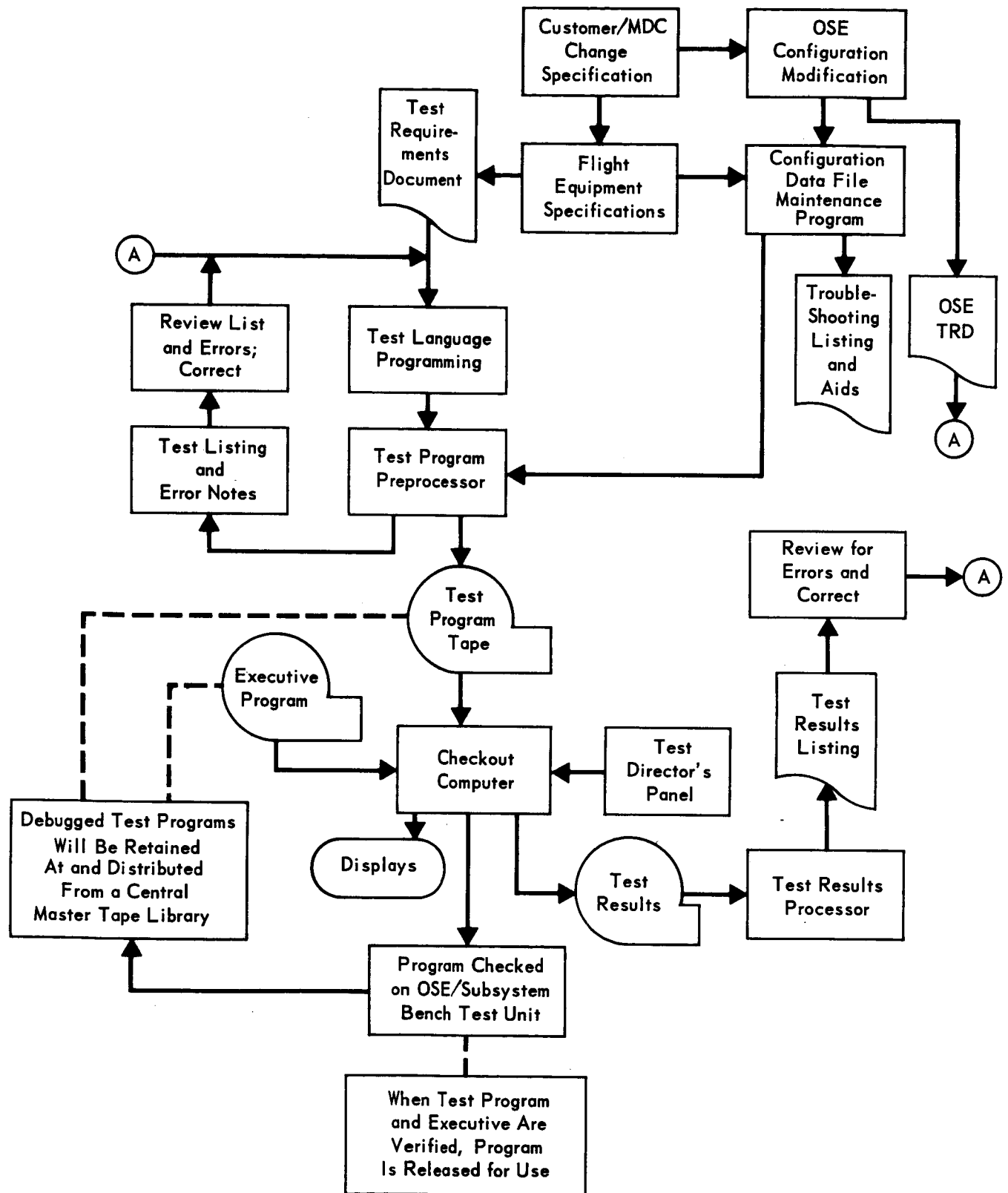When Test Program and Executive Are Verified, Program Is Released for Use

Figure 8.8-1

8-36

8.9 SELECTION CRITERIA – Selection of our design concept has been accomplished by weighing alternative design approaches that meet the requirements, against selection criteria developed in accordance with VOYAGER program objectives. The detailed development and application of OSE selection criteria is described in Volume II, Part D, Section 10. A summary of VOYAGER selection criteria and typical OSE selection factors is shown in Figure 8.9-1.

8.10 MAJOR TRADE STUDY SUMMARY – The major OSE trade studies identified during Phase "B" are summarized in Figure 8.10-1. Detailed analyses and selection rationale are contained in Part D, Section 10.

8.11 OSE IMPLEMENTATION – Our OSE design is keyed to VOYAGER program implementation by the use of modular hardware and software packaging, by phased software development, and by paralleling OSE/Flight Systems design in a manner which minimizes the conventional lead time requirements. OSE implementation is discussed in more detail in Part D, Section 1, of Volume VI.

8-37

OSE SELECTION CRITERIA AND FACTORS

PROGRAM CRITERIA	TYPICAL OSE SELECTION FACTORS
Probability of Mission Success	OSE reliability Affect on flight subsystems OSE redundancy and backup
OSE and Flight System Performance	Test quality Test time (operator, OSE, flight system) Test confidence Degree of self test Degree of fault isolation
Development and Schedule Risk	OSE operational availability (MTBF) Relative "state-of-art" OSE initial availability
Versatility (Flexibility)	Growth potential Choice of operating modes Potential common usage Adaptability to future missions
Cost	Test cost (operators time) OSE hardware cost OSE maintenance cost OSE development cost Software cost

SUMMARY OF MAJOR OSE TRADE STUDIES

TRADE STUDY	REMARKS
<u>SSTS Automation</u> Selective Automatic vs Manual Mode	● Minimum Test Time ● Hi Speed Self Check and Alarm Monitor ● Maximum Repeatability and Accuracy ● Cost Effective for Selected Subsystems
<u>STC Displays</u> Digital Displays vs. Analog Meters vs. C RT Displays	● Minimum Operator Error ● Hi Density Display Saves Space ● Max Flexibility and Growth Potential
<u>CB Transportation Mode</u> Barge vs. Highway vs. Helicopter vs. Aircraft	● Least Schedule Impact ● Barge is Backup Mode
<u>CDS Computer Selection</u> SDS 920 vs. 3rd Generation	● Maximum Flexibility & Growth ● Minimum Test Time ● Potential for Contractor time sharing
<u>SSTS Automation Method</u> Hard Wire Logic vs. Tape Reader vs. Desk Top Computer	● Cost Effective for Highly Repetitive Sequential Operations ● Max Flexibility and Growth ● Provides Independent Subsystem Test

Figure 8.10-1

SECTION 9

SYSTEM INTERFACES

This section presents first our preferred approach to System interfaces and our understanding of their influence on overall Flight Capsule design, and second a summarization of CBS interfaces to the other VOYAGER systems. Capsule Bus (CB) to other system interfaces are defined as intersystem (or area) interfaces where relationships exist between two or more systems hardware, procedures, operational support equipment, or operations.

These primarily consist of functional compatibility (physical, electrical, mechanical, signals, etc.) and software (documents, procedures, training, etc.), typically shown in Figure 9-1. Our approach is based on the following considerations, tailored by major space program experience, and VOYAGER Program desires of standardization for future missions.

o Simplicity - to provide maximum system independency

o Definition - clear descriptions of criteria, constraints, function, software, etc.

o Access - to provide interface checkout (flight acceptance testing)

o Responsibilities - delineated custodian and participating system contractor roles

o Control - adequate documentation to provide interface control

9.1 <u>System Interface Evolution</u> - System interfaces evolve as shown by Figure 9.1-1 out of the NASA VOYAGER Program Plans. These interfaces occur because (1) there are seven VOYAGER systems and each system may be awarded to a separate contractor, and (2) separate NASA centers of JPL are assigned responsibility for each system.

System interface requirements first appear during the customer's research, study and definition of seven VOYAGER systems. NASA system specifications document the customer imposed system interface constraints. Participating contractors further determine and evaluate system imposed interface constraints.

Once system interface areas are identified, interface control is needed for coordination among the system contractors. This control is necessary to enable contractor to design and test his System before integrating it with the next level of assemblage, and also facilitates installation, checkout, and operation of systems after integration. Therefore, for VOYAGER, McDonnell has written an Interface Control Plan presented in Volume VI, Part C, Section 9. The main elements of this plan are as follows:

9-1

TYPICAL CBS-TO-OTHER SYSTEM INTERFACES

- EMC
- OSE
- Launch & Launch Pad Environments
- Envelopes

LVS

- EMC
- OSE
- SC Mtd. CB Eqpt.
- Circuit Design
- Thermal
- Struct/Mech
- Command Signals
- Inflight Checkout

- OSE
- MDE
- Facilities
- Special Handling & Safety Procedure
- Launch Operations

LOS

- Operations

SCS

- Routing of SL/SC Cabling (Signals, Power, and Data Lines) thru CB

CBS

- MDE
- Computer Program for Data Reduction
- Operations(SFOF, Procedures & Personnel)
- Capsule Simulator

MOS

- EMC
- MDE
- Thermal
- Struct/Mech
- Circuit Design
- Backup Commands
- Site Contamination
- OSE

SLS

- Operations

TDAS

- ESP/SL Cable Routing thru CB
- Data Interleaving

ESP

- EMC
- OSE
- Thermal
- Struct/Mech
- Circuit Design

- Data Acquisition
- MDE
- DSN

SYSTEM INTERFACE EVOLUTION
CAPSULE BUS SYSTEM

PLANS

- NASA Program
- NASA Organization
- Procurement

- Mission Objectives
- Environments (Incl Predicted & Unknown)
- State-of-the-Art
- Systems Definitions
- Systems Specifications

TECHNICAL
INFORMATION

GROUPS

- NASA Centers (With System Responsibility)
- Scientific Community
- System Contractors

- Interface Control
  - Coordination
  - Organization Rules
  - Documentation
- System Design Processes

CONTROL &
PROCESSES

Production

SYSTEMS INTEGRATION

CBS   ESP   SLS   SCS   LVS   LOS   TDAS   MOS

Flight
Capsule   Planetary
Vehicle   Space
Vehicle   Launch

Mission Support
& Operations
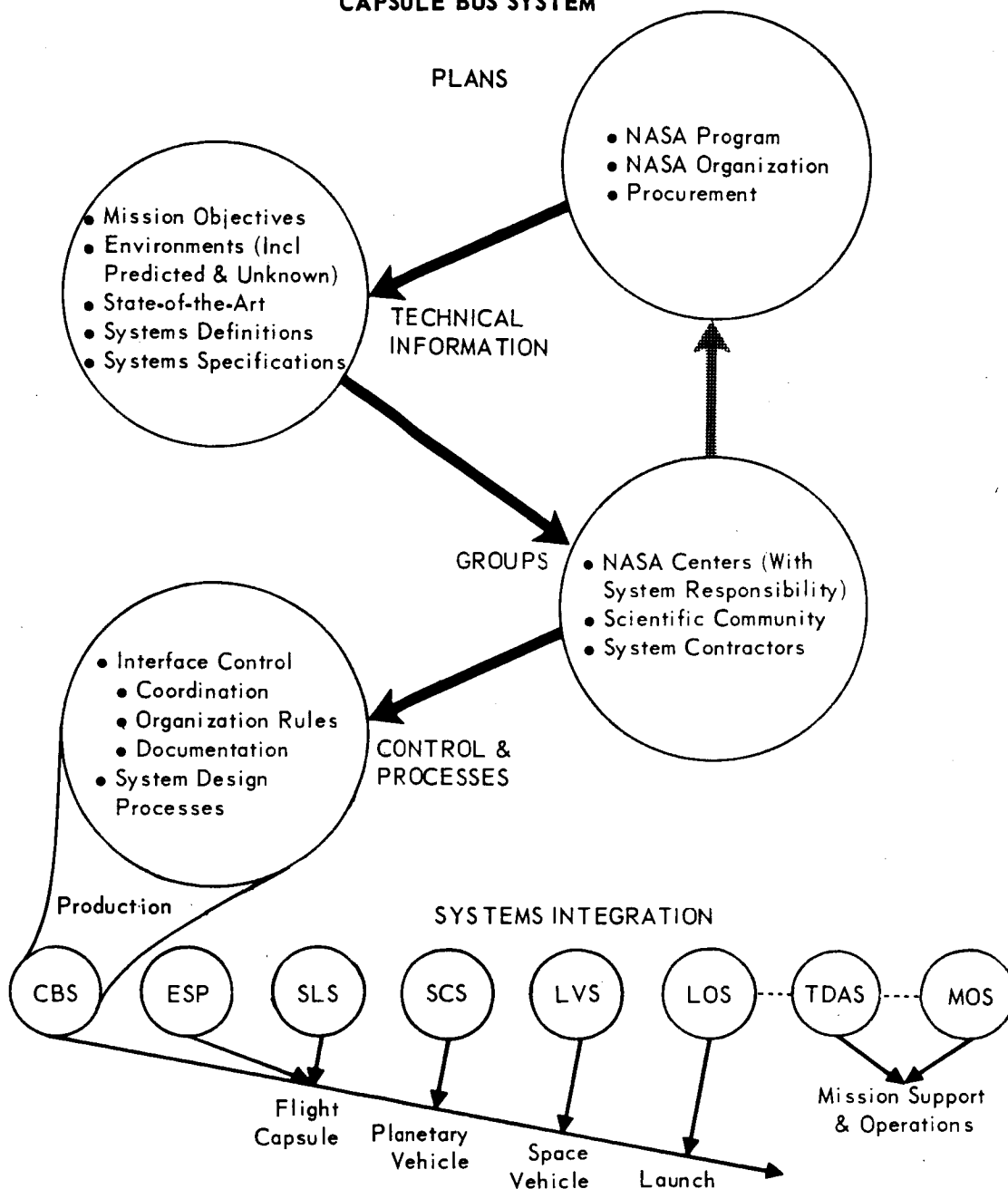
o <u>Interface Control</u> will be under the direction of NASA (NASA Project Office)

o An <u>Interface Control Working Group (ICWG)</u> organization will be founded with members from each System Contractor, JPL, each NASA Center with system responsibility, and the NASA Project Office.

o <u>Control Documents</u> (Interface Specifications, Interface Control Drawings, and change documentation) will be used throughout the program.

o <u>Formal Meetings</u>, namely (1) the Interface Control Meetings - NASA Project Office - will provide top management policy and decisions for each System Contractor, JPL and NASA Center having system responsibility, and (2) the ICWG Meetings will provide coordination of technical agreements, and documentation between system contractors.

o <u>Informal Meetings</u> (e.g., telecons, visits) will provide day to day communications between the system contractors, JPL, and NASA Centers.

Out of iterations of the systems engineering process come system interface design and its hardware verification. This process is summarized in Figure 9.1-2 on the following page.

Proof of hard system interfaces is realized as the various systems are integrated during Phase "D", starting with engineering models (boilerplate construction and engineering prototype equipment) and culminating in flight hardware preparations for launch. Figure 9.1-1 shows sequence of system hardware integrations; CB and SL into a Flight Capsule (FC); FC and SC into a Planetary Vehicle (PV); and then PV and LV into a Space Vehicle. Software interface verification on the other hand, extends into the mission support and operations phases after launch.

9.2 <u>Interface Areas</u> - The seven Voyager Systems functionally interface as shown in Figure 9.2-1. Our concern here is the CBS relationship in this diagram. Hardware (power distribution, data/signals, commands, structural/mechanical, and relatively few backup relationships), OSE, operations, and software interfaces are shown in Figure 9.2-2. An example of how to read this matrix is: a "power distribution" interface between the CB and ESP is "CB distributes regulated SC power to ESP". Another example is: an "OSE" interface between the CBS and ESP is "stimulus and monitor signals for integrated testing (between the CBS and ESP OSE)". The follow-paragraphs briefly discuss these system interface areas as related to the Capsule Bus System. Volume V, Part B details each of these.

9.2.1 <u>CBS-To-SLS</u> - For the CBS and SLS, physical, signal, and thermal interfaces exist between the CB and SL. Also this interface area includes OSE, operations and software.

SYSTEMS ENGINEERING EVENTS AFFECTING INTERFACES

ACTIVITY	INTERFACE CONSIDERATION
System Trade Studies	Study of all practical approaches to interface.
System Analysis	Analysis of approaches for most practical and best selection (based on state-of-the-art, constraints, etc.)
Design Milestones	
● Preliminary Design	Selection of preliminary concept with alternatives
● Concept Freeze	Selection of preferred concept
● Specification Control Drawings (SCD's) Completion	Inclusion of system interfaces
● System Specification	Definition or interface criteria constraints
● Part I Contract End Item (CEI) Specification	Inclusion of interface requirements
● Preliminary Design Review (PDR)	Verification of interface requirements
● SCD's Release	Documentation of system interface provisions on drawings
● Interface Specification and Interface Control Drawings Release	Documentation of system interface provisions on drawings
● Design Release	Documentation of system interface provisions on drawings
● Critical Design Review (CDR)	Verification of interface requirements designed
● Part II CEI Specs	Inclusion of system interface requirements
● First Article Configuration Inspection (FACI)	Verification that interface requirements were complied with

Figure 9.1-2

9-5

VOYAGER SYSTEMS FUNCTIONAL BLOCK DIAGRAM

(—→ FUNCTIONAL AND SOFTWARE INTERFACE)
(— →SOFTWARE INTERFACE)

CBS ESP SLS SCS LVS – LOS

The PV and LV integrate into a Space Vehicle (SV) at KSC.

LOS provides launch operations, (complex facilities, logistics, personnel-supported by each system, and all SV umbilical cables).

Tracking and Data Acquisition System

Provides the DSN and all other DOD tracking and data acquisition stations and vehicles, NASCOM, personnel, and associated facilities.

Mission Operations System

Provides the MDE at DSN sites, KSC and AFETR, the computer programs, operation teams in the SFOF and all other facilities supporting MOS

CBS ESP SLS SCS

The FC and SC integrate into a Planetary Vehicle (PV) at KSC.

LVS

Provides the Launch Vehicle (LV) and Shroud to deliver the PV in Martian Trajectory. This includes associated software, spares, OSE, and personnel.

CBS/ESP/SLS

The CB and SL integrate into a Flight Capsule (FC) at CBS facilities.

SCS

Provides the Spacecraft (SC) to deliver the FC into Martian orbit, relay data from CBS and SLS, and provide Martian orbital science data. This includes associated software, spares, OSE, test models, facilities, and personnel.

CBS

Provides the Capsule Bus (CB) and integrated entry package including associated softwares, spares, OSE, test models, facilities, and personnel. The CB is to deliver the EP to Mars atmosphere of the SL to the Mars surface.

ESP

Provides the Entry Science measurements and supporting subsystems equilment including software, spares, OSE, test model equipment facilities and personnel.

SLS

Provides the Surface Laboratory (SL) which is comprised of landed science experiments, instrumentation, and data transmission units. This includes associated software, spares, OSE, test models, facilities, and personnel.
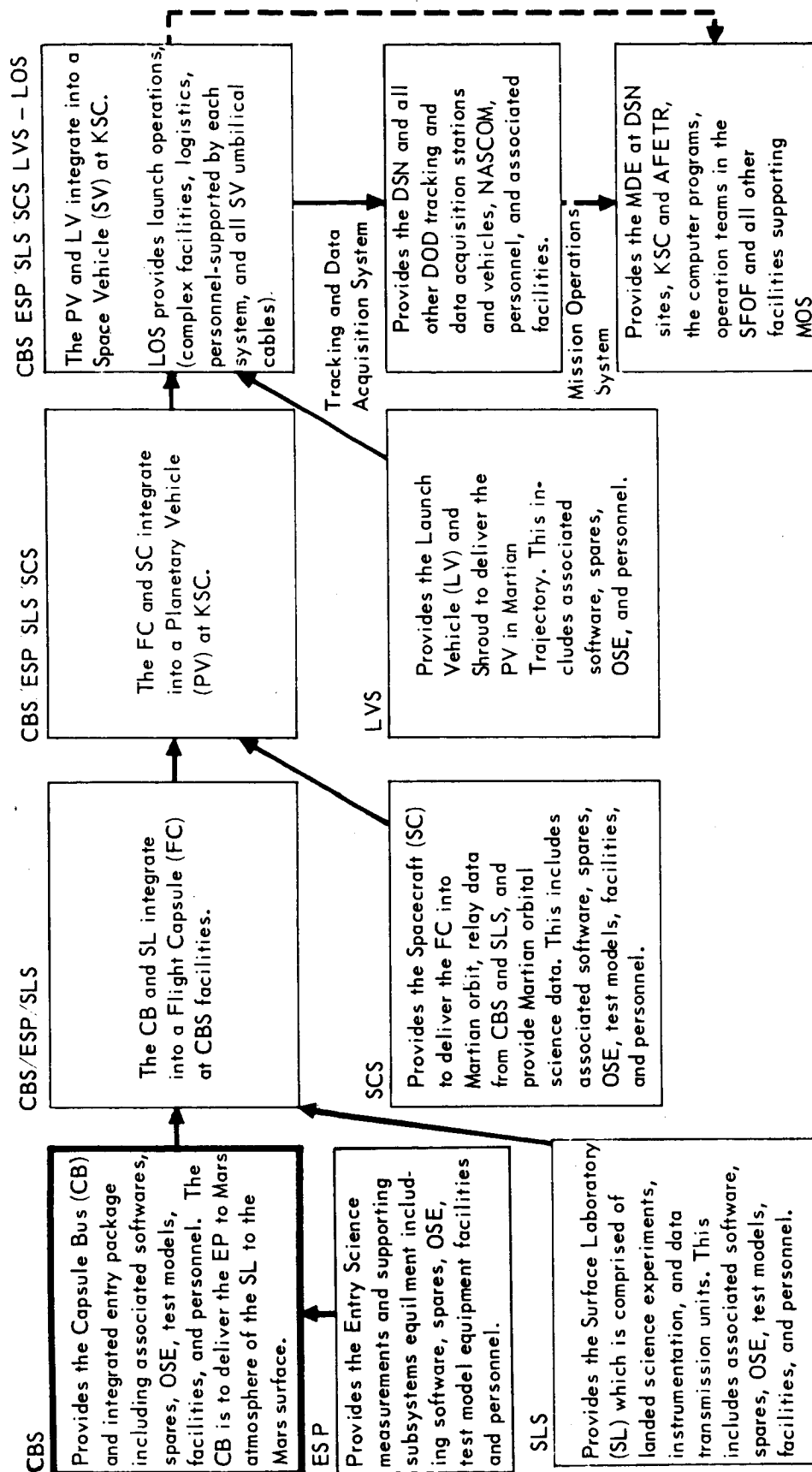
Figure 9.2–1

9–6

9.2.2 CBS-To-ESP - For the CBS and the ESP that is integrated within the Capsule Bus, physical, signal, and thermal interfaces exist. Also, this interface area includes OSE compatibility, operations, and software.

9.2.3 CBS-To-SCS - The CBS and SCS present physical, signal, power, environmental control, and RF interfaces between the Capsule Bus and Spacecraft. Also, interfaces occur between their associated OSE in the system test complexes and in the launch complex equipment. The physical interface between the OSE of the CBS and the SCS includes the connectors on the interconnection cables. Other interfaces that exist are maintenance of sterilization levels, operations and software.

9.2.4 CBS-To-LVS - The major interface between the CBS and LVS is that of environmental control; temperature, humidity, and cleanliness under the nose fairing is maintained by the LVS. To define this area in detail, we must also consider the SCS as well as the CBS and LVS. Envelope constraints of the LV are also entailed.

9.2.5 CBS-To-LOS - This interface involves physical and functional support for launch preparations and launch activities.

9.2.6 CBS-To-TDAS - The CBS-To-TDAS interfaces involve the telemetry to all tracking and data stations assigned to the VOYAGER mission. These interfaces are the S-Band downlink via the Spacecraft. Also, the CBS MDE and Flight Capsule simulator have physical, power, and signal interfaces with TDAS stations.

9.2.9 CBS-To-MOS - The CBS and MOS have functional interfaces in the command and telemetry data streams. Commands originated and verified by the MOS teams constitute the command data stream. They cross the MOS-To-TDAS and TDAS-To-SCS interfaces through the Spacecraft to the Capsule Bus. Data for command verification is fed back from the Capsule through the Spacecraft to the MOS via the telemetry data stream. This data stream, which starts in the CBS, crosses the SCS-To-TDAS and TDAS-To-MOS interfaces before reaching MOS teams. Other interfaces possibly exist where data from CB systems test and other VOYAGER systems test data pass to the MOS, including computer data reduction and analysis programs. Training and procedural interfaces are also involved for the operation of MDE and for post launch decisions.

9-7

	ENTRY SCIENCE PACKAGE (ESP)	SURFACE LABORATORY SYSTEM (SLS)	SPACECRAFT SYSTEM (SCS)
F L I G H T H A R D W A R E	**Power Distribution** CB distributes SC regulated power to ESP CB distributes SC power for ESP heaters SC signals to ESP (via CB) to switch to internal power and switch to SC power **Data Signals** CB to ESP telemetry sync, word sync, frame sync and clock signals ESP to CB cruise data CB distribution of ESP to SC data and data sync for TV checkout CB distributes to SC the ESP parasitic antenna test signal **Command** CB command to turn on and off ESP electrical power SC central computer & sequencer command (to ESP via CB), turn on cruise commutators CB to ESP terminate terminal thrust command CB to ESP inflight checkout data sync and control commands **Structural/Mechanical** CB protection (thermal) of ESP during cruise CB mounting provisions of ESP accelerometer, stagnation transducers, descent imagers, stagnation vent tube, 2 UHF antennas, and separation devices CB alignment provisions for ESP accelerometer Heat transfer at field joints **Backup** CB distributes SL backup power to ESP CB commands to ESP electrical power subsystem CB engg data to ESP (incls delayed data) ESP to CB engg and low rate science data CB to ESP aerodeceleration deployment sequence and initiate signal CB to ESP radio subsystem commands	**Power Distribution** CB distributes regulated SC power to SL CB distributes SC power for SL thermal control heaters **Data Signals** CB frame sync, word sync, and clock signals to SL SL cruise data to CB **Command** CB distributes SC turn-on of SL command subsystem CB distributes SC turn-on of SL sequencer and timer CB signal for SL to turn on cruise commutators CB commands to SL for inflight checkout control CB distributes commands and command sync signals to SL **Structural Mechanical** CB temperature monitoring cruise and entry protection for SL by CB CB terminal propulsion site contamination and alteration - affects SL science measurements as to time, depth and location CB structural provision for deployable instruments (eg., soil sampler) Imager viewing access Heat transfer at CB SL field joint SLS radiator view to space Mechanics of CB SL field joint Antenna installation and alignment CB and SL plane of aeroshell separation Envelope restrictions and cg. location **Backup** Post landed CB battery power supplied to SL SL backup power to CB CB distributes SL backup power to ESP CB signal for SL to switch to internal power CB signal for SL to switch to SC power	**Power Distribution** SC power supplied to CB (incl. short circuit protection) SC signals to CB to switch to SC power and switch to internal power **Data Signals** CB inflight checkout data and data sync to SC CB distribute CB, ESP and SL cruise data to SC CB entry RF signal to SC SC to CB frame sync and clock signals CB distributes to SC ESP inflight checkout TV data and TV data sync signals CB distributes to SC inflight checkout data and data sync signals CB to SC parasitic antenna test signal **Command** CB to SC test sequence status and inflight checkout commands SC to CB signals to turn-on cruise commutators, and to turn-on CB sequencer and timers SC to CB signal to apply full heater power (canister) SC to CB signals to prepare FC for separation and to start separation sequence SC to CB signal to begin inflight checkout CB distribute SC signals to turn-on and start sequencer and timer SC to CB signals to turn-on command subsystems, to initiate commands and command sync **Structural Mechanical** SC instruments and structure impingement during separation and deorbit thrusting CB thermal isolation covers and barriers SC to CB mechanical transfer for alignment
O S E	Stimulus and monitor signals for integrated testing (between CBS and ESP OSE) ESP OSE physical interface with CB STC ESP to CBS ground station RF data link ESP and CB simulators for premate testing	Stimulus and monitor signals for integrated tests Simulators (CB & SL) for premate tests OSE for SL handling at CB contractor's plant SLS OSE physical interface with CBS STC CB & SL OSE test procedures for integrated tests CB & SL simulator maintenance procedures SL OSE integration schedules	SC and CB simulators for premate tests CB telemetry, test data and critical analog signals through the SC umbilical SC and CB STC (OSE) compatibility
O P E R A T I O N S	OSE test procedures OSE integration schedules Launch abort procedures for ESP science instruments Personnel hazard areas - ESP safety inputs Post-launch decisions	Procedures for tests - FC & PV - operating sequences SL hardware integration schedules Mission contingency plans SL equipment special handling procedures Post-launch decisions	OSE test procedures Launch site OSE integration schedules CB and SC procedures for PV integrated tests Post-launch decisions Operations procedures (CB and SC)
S O F T W A R E	ESP test plans integrated into CB test program for integrated tests Time histories (altitude, attitude, attitude rate, roll axis acceleration, and range radar) OSE maintenance procedures Design requirements coordination (EMC, environment, isolation, etc.) Other documents (schedules, logic drawings, interface specifications and control drawings and their changes)	Design requirement coordination (EMC, environment, isolation, etc.) Documents (schedules, logic drawings, interface specifications, interface control drawings, and their changes)	Test plans Arrival geometry Trajectory information Design requirements, coordination (EMC, environment, isolation, etc.) Other documents (schedule, logic drawings, interface specifications and control drawings, and their changes)

9-8-1

LAUNCH VEHICLE SYSTEM (LVS)	LAUNCH OPERATIONS SYSTEM (LOS)	TRACKING AND DATA ACQUISITION SYSTEM (TDAS)	MISSION OPERATIONS SYSTEM (MOS)
LV provides for PV environmental control within nose fairing shroud after mate (temperature humidity cleanliness) Envelope constraints on CB		Telemetry and command link (via SC) to all VOYAGE TDAS stations during cruise and entry	
	CB OSE integration at pad, explosive safe facility (ESAF) and SC integration facility CB MDE integration at DSIF71	CB telemetry and command simulator in DSN (at TDAS stations) CB MDE integration in DSN (at TDAS stations)	MOS personnel to operate CB MDE
Lift-off, boost, and insertion into Mars orbit	Special handling operations for CB equipment Launch operation procedures	Tracking for preloaded operations	Functional support for command data stream (MOS originated and verified) Functional support for telemetry data stream (CB originated) Contingency plans Post-launch decisions MOS personnel training to operate CB MDE
SV test plans Schedules	LOS safety procedures LOS logistics for CB support	Tracking information CB MDE requirements	FC simulator procedures MOS computer software SFOF mission analysis CB system test data to MOS

Figure 9.2–2

SECTION 10

IMPLEMENTATION

Successful development of the VOYAGER Flight Capsule requires a plan of action that assures a mission-quality vehicle. The Implementation Plan complements the technical approach presented in the previous sections of this volume, reflects a consideration of the mission objectives, requirements, and contraints, and integrates twenty-one element plans into one plan of attack.

Basic assumptions and ground rules applied to the development of this plan are:

a. Provide four identical Flight Capsules for the 1973 opportunity.

b. The Capsule Bus System contractor integrates the Surface Laboratory and the Entry Science Package to produce a Flight Capsule.

c. A launch period from 7 August to 6 September 1973 is utilized for the preferred design. However, if a landing near the evening terminator were used, the launch period is from 16 July to 6 September 1973. To retain a time contingency, the 16 July date is used for all planning and schedules.

d. Phase C starts 1 June 1968 abd ends 29 February 1969. Phase D starts 1 March 1969 and continues to VOYAGER Program objective accomplishment.

o Scope - The Implementation Plan, presented in Volume VI, provides a definitive description of the planned effort, the facilities, and the management controls that are necessary to produce a mission-ready Flight Capsule. It specifically establishes the time-phased sequence of events necessary for the design, development, fabrication, assembly and test of the Capsule.

The hardware implementation aspects of the Capsule Bus System are discussed in Section 2, Part B of Volume VI. A summary of that discussion is presented in subsequent paragraphs of this section. Individual implementation plans are presented, in summary, for twenty-one project functions of Product Development, Product Support, and Management Control as illustrated in Figure 10-1. Each of the plans as discussed in Volume VI, define the tasks, events and activities necessary for Capsule development within their respective function.

o Major Constraints - Flight Capsule studies have identified four major constraints that affect the implementation planning.

a. The inflexible launch period

b. Planetary Quarantine requirements

c. Science-experiment integration

ELEMENT PLANS OF THE
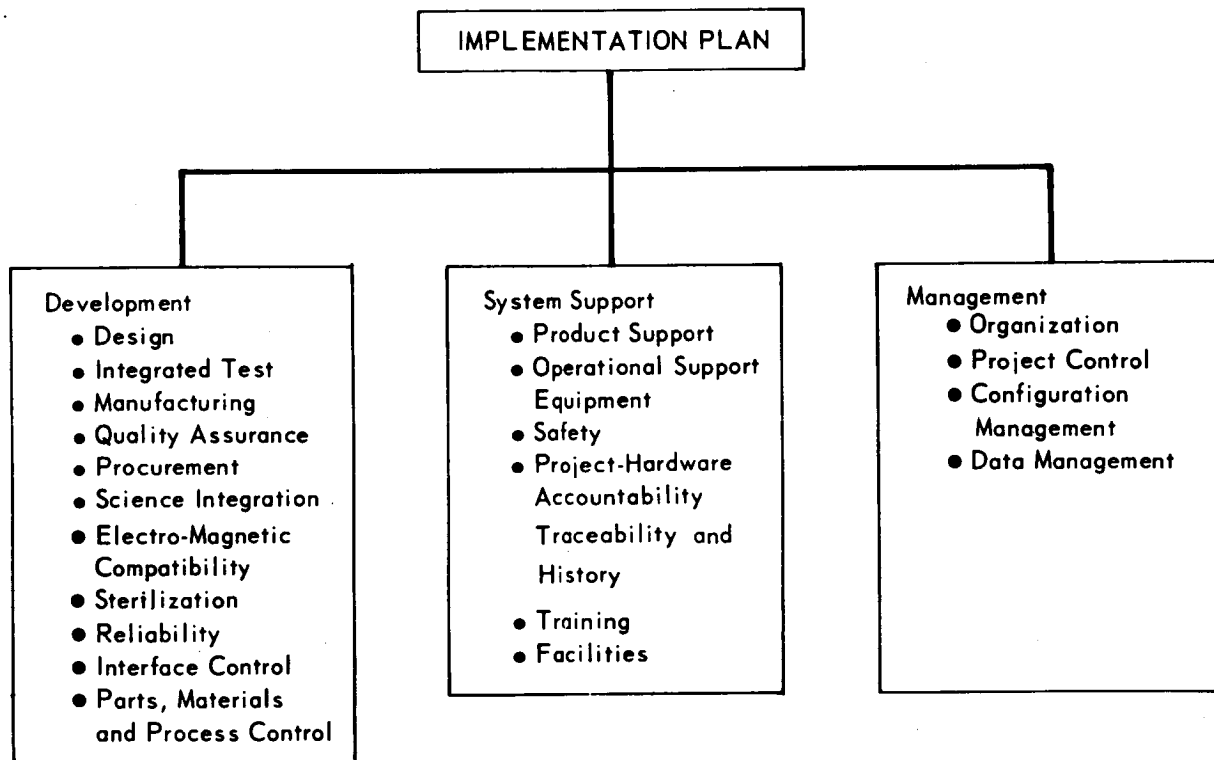## VOYAGER FLIGHT CAPSULE IMPLEMENTATION PLAN

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                    ┌─────────────────────────┐
                    │  IMPLEMENTATION PLAN     │
                    └─────────────────────────┘
```

Development
- Design
- Integrated Test
- Manufacturing
- Quality Assurance
- Procurement
- Science Integration
- Electro-Magnetic Compatibility
- Sterilization
- Reliability
- Interface Control
- Parts, Materials and Process Control

System Support
- Product Support
- Operational Support Equipment
- Safety
- Project-Hardware Accountability Traceability and History
- Training
- Facilities

Management
- Organization
- Project Control
- Configuration Management
- Data Management

d. Interface multiplicity

o <u>Launch Period</u> - The inflexible launch period demands that precise schedules be established and controls exercised to insure that the Flight Capsule is flight-worthy before the first day of the launch opportunity. The master Flight Capsule schedule must have sufficient flexibility for contingencies, which past experience has taught us to expect, and must be well coordinated with the schedules of other major systems.

o <u>Planetary Quarantine</u> - The Planetary Quarantine requirements increase the time and cost required for total system development. The impact of the sterilization requirement is initially felt at the part/piece level, since part selection must be more stringent than in previous programs. At subsystem, system, and final assembly levels of fabrication and test, the microbiological monitoring, the decontamination and the cleanliness control that are required increase the complexity of techniques, procedures, OSE, and facilities. Extensive part identification and control are required so that part traceability, microbiological loading, and reliability data can be provided on rapid recall.

o <u>Science Experiment Integration</u> - The restrictive launch period and the planetary quarantine constraints require that experiment integration be accomplished with particular care, and in conjunction with the development of other subsystems. Prototype, qualification and flight acceptance hardware is required at the appropriate time in the proper configuration, in accordance with the Integrated Test Plan.

o <u>Interfaces</u> - Capsule Bus interface coordination with other systems requires a constant information flow. This means providing software and hardware inter-system interface control, with assistance, on time, in depth, as required.

10.1 <u>Basic Subsystems and Modules</u> - The preferred VOYAGER Flight Capsule concept configuration is composed of twenty basic subsystems assembled into seven major modules. The basic concept configuration is illustrated in Figure 10-2. The Capsule Bus basic subsystems are illustrated in Figure 10-3. Of the twenty basic subsystems in the Flight Capsule, seventeen are germane to the Capsule Bus. These seventeen subsystems are assembled into five of the major modules which are: 1) Canister, 2) Adapter, 3) Aeroshell, 4) Lander, and 5) Deorbit Motor.

10.2 <u>Schedules and Analysis</u> - A summary master schedule for the Capsule Bus System is included as Figure 10-4. This section highlights the key events planned in this schedule, the time critical subsystems identified through our schedule
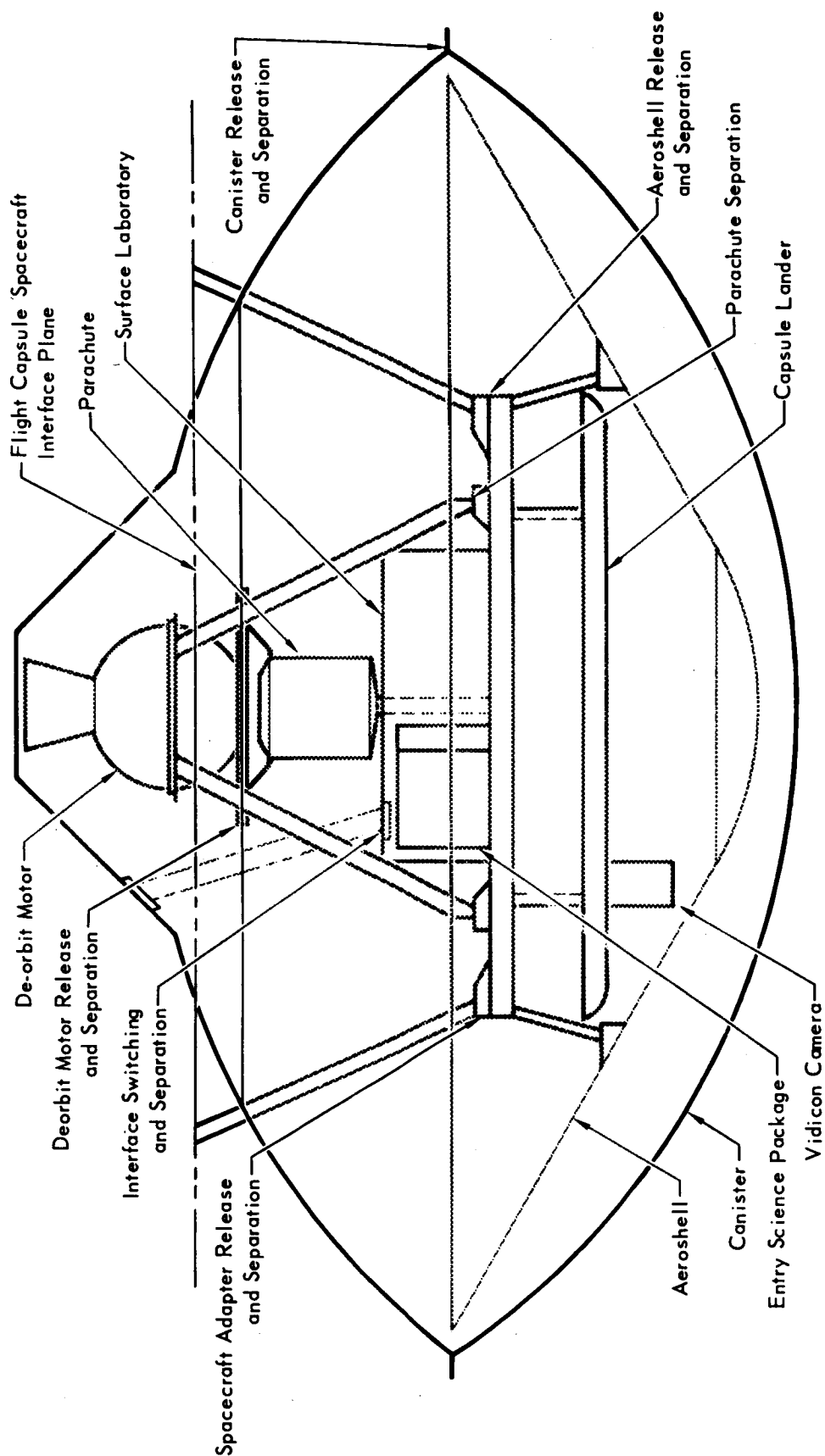
10-3

VOYAGER FLIGHT CAPSULE

Canister Release and Separation

Aeroshell Release and Separation

Flight Capsule Spacecraft Interface Plane

Surface Laboratory

Parachute

Parachute Separation

Capsule Lander

De-orbit Motor

Deorbit Motor Release and Separation

Interface Switching and Separation

Spacecraft Adapter Release and Separation

Aeroshell

Canister

Entry Science Package

Vidicon Camera

CAPSULE BUS SUBSYSTEMS

CANISTER AND ADAPTER

Power Subsystem

Sequencer Subsystem
- Test Programmer

Telemetry Subsystem
- Instrumentation
  - Transducers
  - Signal Conditioners
- Data Commutator

Cabling Subsystem

Pyrotechnic Subsystem
- Canister Release Assy.
- Mechanisms
  - Release Devices
  - Separation Sensors

Thermal Control Subsystem
- Heaters
- Thermostats
- Insulation
- Coatings

Structure/Mechanical Subsystem
- Forward Canister Assy
- Aft Canister Assy
- Canister Separation Assy
- Pressurization And Venting
  - Biological Vent Filters
  - Venting Nozzles
  - Biological Line Filters
  - Vent Valves
  - Purge & Evacuation Valves
  - Relief Valves
  - High Pressure Gas Tank
  - High Pressure Regulator
  - Pressure Transducer
  - Temperature Transducer
  - Fill Valve

CAPSULE BUS

Power Subsystem
- Battery, Main (2)
- Battery, Squib (2)
- Battery Charger
- Power Switching & Logic
- DC to DC Converters (2)

Sequencer Subsystem
- Sequencer & Timer
- Test Programmer

Guidance and Control Subsystem (GCS)
- Inertial Measurement Unit (IMU)
- Guidance & Control Computer (GCC)
- Guidance Power Supply (GPS)

Guidance Sensor Subsystem (Radar)
- Landing Radar
  - Antenna Assembly
  - Altimeter Antenna
  - Electronics Assy
- Radar Altimeter
  - Electronics Altimeter
  - Array Anetnna

Radio Subsystem
- Low Rate UHF Transmitter
  - Modulator
  - Power Amp

Antenna Subsystem
- Antenna(s)
- Diplexer, Hybrids, etc
- Checkout Components

Command Subsystem

Telemetry Subsystem
- Instrumentation
  - Transducers
    - Pressure
    - Temperature
    - Acceleration
  - Signal Condition
  - Instrumentation
- Commutation – De
  - Master Control
  - Engineering Dat
  - Cruise Commuta
  - CB/EP Data Inte

Data Storage Subsyst
- Delay Storage
- R/T – D/T Interl

Cabling Storage Subs

De-Orbit Subsystem
- Spherical Solid
  - Rocket Motor
  - Nozzle with
  - Ball Release
  - Igniter Assy
- Structural Assy

Reaction Control Su

GN$_2$ Pressure Tank Assy	Bur Rel
Tank	Pro
Regulator	Ass
Pyro Valve	F
Fill Valve	T
Filter	C

- Check Valves
- Shut-off Valve
- Pyro Valve Assy
- Filter Assy
- Access Ports and Connecting Lines

Figure 10-3

10-5-1

Terminal Propulsion Subsystem

Fuel Supply
- Tank
- Pyro Valve
- Fill Valve
- Filter
- Check Valve
- Burst Diaphragm & Relief Valve

Pressurant Assy
- Tank
- Pyro Valve
- Fill Valve
- Filter
- Regulator
- Shut-off Valve

Oxidizer Supply
- Tank
- Pyro Valve
- Fill Valve
- Filter
- Check Valve
- Burst Diaphragm and Relief Valve

Throttleable Engines (6)
- Throttling Valves
- Shut-off Valves

Engine Gimbal Actuators

Access Parts & Connecting Lines

Structural Mechanical Subsystem

Aeroshell
- Nose Cone Assy
- Heat Shield Assy
- Radome & Window Assys
- De-orbit Motor Support
- Separation Assys

Lander
- Lower Equipment
- Upper Equipt Assy
- Impact Assy
- Separation Assys

Thermal Control Subsystem
- Heaters
- Thermostats
- Insulation
- Coatings

Aerodynamic Decelerator Subsystem
- Decelerator
- Structure & Mechanisms
  - Deployment
  - Cover
  - Infaltion
  - Attachment
  - Release

Pyrotechnic Subsystem

(partial left-margin text cut off at page edge:)

ing
Power Converter
coding

a Commutator
or
rleaver
em

eaver

ystem

system

st Diaphragm &
ief Valve
pellant Tank
y
ill Valve
ank
heck Valves

Propellant Isolation
Valve Assy
Thrust Chamber Assy
- Thrust Chambers
- Propellant Valves

VOYAGER CAPSULE BUS SYSTEM SUMMARY SCHEDULE

ACTIVITY	1968							1969												
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

PHASE C ----------------------------- ▽ Go-Ahead
  Preliminary System Design Completed -------------- ▽
  System Layouts Completed ------------------- ▽
  Detailed Subsystem Design Completed --------------- ▽
  Part I CEI Specs Completed and Submitted ------------- ▽
  Preliminary Design Review --------------------- ▽
  Final Definition of Critical Subsystems -------------- ▽
  Critical Subsystems Breadboard Fabrication ---------------
  Critical Subsystems Breadboard Testing ---------------
  Planetary Quarantine-Initial Certification of Personnel
    and Facilities ----------------------- ▽
PHASE D ----------------------------- ▽ Go-Ahead
  Engineering
    90% Design Release ----------------- Structural ▽
    Critical Design Review ----------------------
    Part II CEI Specs Submitted ----------------
    First Article Configuration Inspection -------------
  Subsystem Development
    Purchase Orders (PO) Placed ------------------
    Major Subsystems Development Testing -------------
    Major Subsystems Qualification Testing -------------
    Flight Vehicle No. 1-Subsystems Available -----------
  Flight Vehicle No. 1-SLS and ESP Required ------------
  Manufacturing
    Begin Detailed Parts Manufacturing --------------- ▽
    Begin Test Article Fabrication ----------------- ▽
    Flight Vehicle No. 1 Structural Assembly -------------
    Flight Vehicle No. 1 Subsystem and Equipment Installation
    Flight Vehicle No. 1 Phase I and II Tests ------------
    Verification of Accumulated Biological Load ----------
    Flight Vehicle Deliveries to KSC ---------------
  Compatibility Testing – Engineering Model
    SLS, ESP & Subsystems Testing and Integration ---------
    Integrated Systems Tests -------------------
  Qualification Testing
    Perform Terminal Propulsion Thermal Testing ----------
    Perform Aerodeceleration Testing -------------
    Perform Static, Dynamic and Thermo Testing ----------
  Facilities
    St. Louis Sterilization Facility and Class
    100 Clean Rooms – Operation and Certification --------
  Operational Support Equipment (OSE)
    Factory – Installation and Validation ------------
    KSC – Installation and Validation -------------
  Launch Operations
    Flight Vehicles No. 1 and No. 2 Phase III and IV
    Tests – Terminal Sterilization ---------------
    Flight Vehicles No. 1 and No. 2 Launch ------------

F M A M J J A S O N D | J F M A M J J A S O N D | J F M A M J J A S O N D | J F M A M J J A S O N D

21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67

Electrical

At Contr.

At KSC

Phase I   Phase II

FC-1   -2   -3 -4

Compatibility

Update & Mission Life Test

10-6-2

analysis and the provisions for contingency included in our planning.

10.2.1 <u>Key Schedule Dates</u> - During the first two months of Phase C, a detailed review of subsystem development requirements will be conducted to augment our preliminary analysis and define the time critical subsystems. This early identification will permit adequate time during Phase C to begin breadboard and development of these critical subsystems. Detailed subsystem design is scheduled to complete 2 months prior to the Part 1 CEI submittal date. This is to allow time for incorporation of design data into the specification prior to the Preliminary Design Review.

During Phase D, the critical design review is scheduled to begin 19 months after go-ahead and 12 months prior to the start of flight vehicle No. 1 structural fabrication. This scheduling is late enough to obtain a definite design supported by subsystems compatibility in the Engineering Model Vehicle, while being early enough to effectively implement changes in the development and manufacturing operation. The fabrication of test articles begins in October 1969. This early availability of test vehicles will allow a progressive series of component, subsystem, and system testing to allow an early identification of system development problems. All qualification testing is scheduled to complete prior to delivery of first Flight Vehicle. This time period allows any problems discovered in qualification testing to be resolved and incorporated into the first flight vehicle. The Class 100 Clean Room is scheduled for certification and ready for the assembly build-up of the first production type vehicle. Operational Support Equipment both for the factory and launch site have been scheduled to be validated and ready for operation approximately 3 months prior to their first usage. Flight vehicle assembly and system checkouts have been scheduled at the factory such that a minimum amount of system testing will be required at the launch site. Delivery of the 1st flight vehicle to the launch site is scheduled to permit checkout prior to the first Planetary Vehicle being mated to the Launch Vehicle.

10.2.2 <u>Critical Subsystems</u> - The milestones identified on the master schedule were analyzed through the development of numerous plans and schedules and integrated through the processing and review of over 5,000 PERT network activities. The following subsystems were identified as time critical:

Critical Subsystem	Critical Item	Approximate Weeks Criticality
Terminal Propulsion	Component development and testing of rocket engines	-18
Reaction Control	Component and development testing of rocket engines	-6
Data Storage	Development and testing of memory core units	-5
Telemetry	Programmer development and testing	-4
Radio	Selection of transistors and development and testing of exciter/power amplifier	-3

The critical subsystems noted above were those remaining after all feasible Phase D replanning efforts have been completed. It was, therefore, determined that the components within these subsystems must begin development during Phase C. It is recognized that the criticality for four of these subsystems is small and will require further investigation during the early part of Phase C to substantiate this advanced effort. The Terminal Propulsion Rocket engines will definitely require some development efforts in Phase C.

10.2.3 Contingencies - The master schedule and the more detailed schedules supporting it, include planned provisons for recovery in the event of unexpected delays in the program. These provisons can be eliminated at increased risk and/or cost.

o Subsystem Development - The subsystem development flow consists of constraints for breadboard performance and qualification testing on the releases of design for prototype and production hardware. For example, the design release for manufacturing prototype hardware is constrained by a completion of 50% of the performance and sterilization testing. A relaxation of the constraint to only 25% completion of this testing would allow an earlier buildup and delivery of test and flight articles for many of the subsystems. Assembly operations are planned for a two shift, 40 hour work week. The capability, therefore, exists for third shift and extended work week operations. The fabrication of the 10 production vehicles reflects no learning. Should an 85% learning curve be accomplished the availability of the first flight vehicle could be fabricated approximately 17 weeks earlier.

o System Test - Structural, dynamic, and thermal testing has been scheduled

10-8

such that an average of approximately 10 months is allowed for redesign, fabrication and retesting should any major failures occur during testing, and still allow the test results to be incorporated in the first flight vehicle's equipment prior to its installation into the flight capsule. The current plan provides for flight vehicles 1 and 2 to be in storage and monitoring approximately 4 and 2 months respectively. This time may be reduced if necessary. It serves as a final contingency for vehicle availability to meet the unalterable launch period. Flight vehicles 3 and 4 are available as back-up since identical qualified subsystems are installed in all four capsules. The flight vehicles are scheduled for delivery such that 2 major pad recycles, coupled with the usage of flight vehicles 3 and 4 can be accommodated within the expected launch period.

10.3 <u>Manufacturing Schedule and Flow Plan</u> - Contained in this section are the manufacturing schedule and flow plan for the VOYAGER Flight Capsule, of which, the Capsule Bus System (CBS) is the integrating system. It shows the scheduling of functions required to produce the CBS, starting with engineering design and proceeding through production of all test and flight articles. Production of the CBS, with integration of the Entry Science Package (ESP), and the Surface Laboratory System (SLS), results in completion of the Flight Capsule. This section illustrates the manufacturing flow of a typical flight article through the various stages of production and acceptance testing, and includes the points at which the ESP and SLS are integrated into the CBS. This flow includes decontamination, flight acceptance testing, and preparation of the completed VOYAGER Flight Capsule for shipment to the launch site.

10.3.1 <u>Manufacturing Schedule</u> - The Capsule Bus System manufacturing schedule, shown as a part of Figure 10-5, has been prepared with contingencies for the start/completion time cycles for subsequent units of the same item to reflect an efficient use of tooling and manpower. The schedule determines need dates for items furnished by vendors, major subcontractors, and the customer.

10.3.2 <u>Manufacturing Flow Plan</u> - Figure 10-6 is a manufacturing flow plan for the Capsule Bus System, and is for a typical flight article. The plan shows manufacturing of equipment, subsystems, and installations at the required times which will affect ease of handling and also produce a continuous flow peculiar to the Capsule Bus System. Figure 10-7 is a pictorial representation of the same manufacturing flow plan.

10.4 <u>Integrated Test Plan</u> - The purpose of this comprehensive test plan,

VOYAGER FLIGHT CAPSULE
MANUFACTURING SCHEDULE

AEROSHELL

DE-ORBIT MOTOR SUPPORT

CAPSULE LANDER

CANISTER

ADAPTER

FLIGHT VEHICLE 4

FLIGHT VEHICLE 3

FLIGHT VEHICLE 2

FLIGHT VEHICLE 1

STATIC 3 (Thermal Qual)

STATIC 2 (Dynamic Test)

STATIC 4 (PTM)

Subassembly Major Assembly Install Equipment Phase IA Test
Phase IA Testing Lander Phase II Integrated Test Prep Ship
Mate Install Equip IA Dec Aft Canister & Adapter
Assy Weld Mate P T D Install Equip IB Dec Forward Canister
Fabrication Con IA Con
Fabrication Assy

| 16 23 30 | 7 14 21 28 | 4 11 18 25 | 2 9 16 23 30 | 6 13 20 27 | 3 10 17 24 | 1 8 15 22 29 | 5 12 19 26 | 3 10 17 23 30 | 7 14 21 28 | 4 11 18 25 | 3 10 17 24 | 7 14 21 28 | 5 12 19 26 | 2 9 16 23 30 | 7 14 21 28 | 4 11 18 25 | 1 8 15 22 29 | 6 13 20 27 | 3 10 17 22 | 1 8 15 22 29 | 5 12 19 26 | 2 9 16 23 | 2 9 16 23 30 | 6 13 20 27 | 1 8 15 22 | 5 12 19 26 | 2 9 16 23 30 | 6 13 20 27 | 1 8 15 22 |
| Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |

1971 — 1972 — 1973

10-10-2

Torque Box Assemblies

Uni-Disc Struct. Ass'y.

Fab. Sheet Metal Details

Form Skins

Fabricate Plumbing Lines | Proof Test

Fabricate Wire Bundles | DIT MCO

EFC Misc-Electron Eqpt (105) Black B

Install Thrusters

Major Structure Assembly—Includes: Transfer of Aeroshell, Surface Lab, Parachute Attachments, Etc. Hard points via Major/or Master Tooling | Install Stabilizers & Rig | Install Wire Bundles and Plumbing | & Fuel Bottles | Inst Ele Pow men

Fab. Honeycomb Details

LANDER

Attenuator – Struct. Ass'y.

Form Skins

Fab. Sheet Metal Details

Assemble Stabilizers (9) | Proof Test | Assemble Cable Assys | Install Cable Assys(8) | EFC Thruster Chambers

Machine Cable Fittings | EPC Reg. & Control Hdw

Fabricate Springs & Detail Parts | Proof Test | Fabricate and Assemble H_2 Pressurant Tanks | EFC

Fab. Stringers

Fab. Sub Ass'ys | Pallet – Structural Ass'y.

Machine Details

Fabricate and Assemble H_2O_4 Oxidizer Tanks | EFC

Machine Stabilizer Fittings | Fabricate and Assemble MMH Fuel Tanks | EFC

EFC Deployment Sys. Components

EFC Battery Chargers

EFC Converter

EFC Switching Logic

EFC Batteries

Fabricate 1.8 Shell Segments

Fabricate Ring Segments

Weld 1st Stage Skin Sections

AEROSHELL

Ablative Material

Assemble 1/8 Section Skin Panels | Install Corrugations | Assemble Quarter Panels, & Install Fairings & Gussets | Splice Panels | Install Ablative Mate

Weld 2nd Stage Skin Sections

Assemble Fairing & Gusset Subassys

Bond Nose Cap

Fabricate 1.8 Shell Segments

Fabricate Corrugations

Mate Interface of De-Orbit Motor S Adapter Via Maj

Fabricate Fairing and Gusset Details

A

Figure 10–6

10–11~1

AFT CANISTER

- Form Hat Sections
- Fab. Skins
- Assemble Fwd. Section
- Form Internal Rings
- Mate Fwd. & Radar Sections | Press. Test
- Assemble Aft Section
- Machine Rings
- Fab. Aft Dome
- Fab. Skins

CANISTER ADAPTER

FWD CANISTER

- Fab. Sheet Metal Details
- Assemble Individual Qtr. Sections
- Assemble 4 Qtr. Sections & Dome | Press. Test
- Form Skins & Hat Sections
- Spin Dome

ADAPTER

- Fab. Tubing
- Weld Assemblies
- Fab. Fittings & Gussets
- Final Assy. Weld & Finish Machine Rings
- Semi-finish Machine Rolled Rings

Mate Fwd. & Aft Canister & Adapter

Fwd Canister | Phase IA Tests | Contingency

Mate Fwd. & Aft Canister & Adapter | Test | Demate

Install W/Bundles | Install Equipment | Manufacture Check | Phase I A Tests | Mate

Aft Canister/Adapter

Fabricate Wire Bundles | DIM CO

EFC VHF Parasitic Antenna

EFC S-Band Parasitic Antenna

| Install Telecommunications Equipment | Install Guidance Control Equipment | Install Radiators | Install Parachute Canister . & Parachute, Rig Cables, and Manufacturing Checks | Phase IA Testing Capsule Lander | Mate Lander & Aeroshell | Phase IB Tests Lander And Aeroshell | Decon |

Equip.

- EFC Radar Antenna
- EFC Radar Altimeter
- EFC Separation Altimeter
- EFC Ranging Radar
- EFC Radar Electronic Eqpt
- EFC Misc. Electronic Eqpt
- Imaging Camera

ESP

SLS

Entry Package (Available)

Surface Lab (Available)

EFC for Phase IA

EFC for Phase IA

Fab. Radiators

Fab Parachute Canister & Attach Fittings

- Fabricate Plumbing | Proof Test
- Fabricate Wire Bundles | DITMCO
- Machine Nose Tip

Install Nose Tip & Ecco Foam

Fabricate Lander Support Fittings

EFC Camera Window

| rial | Cure | Install W/Bundles and Plumbing | Install Equipment | Install Lander Support Fittings & Struts | Install Window | Manuf. Check | Phase IA Tests – Aeroshell |

- Fab Nose Cap
- Capsule Lander, Support and Canister/ Tooling
- Fabricate Propellant Tanks | EFC
- Fabricate Pressurant Tanks | EFC

EFC Thruster Assys

EFC Prop & Reg Control Hdwe

DE-ORBIT MOTOR SUPPORT

- Fabricate Sheetmetal Details
- Fabricate Plumbing | Proof Test
- Lines
- Fabricate Structure | Install W/Bundles | Manuf. Check
- Mate Interface of Aeroshell, etc. Via Major Tooling Finish Machine Rings & Attach Fittings
- Semi Finish Machine Rings
- Semi Finish Machine Attach Fittings
- Fabricate Wire Bundles | DIT MCO

Fabricate Lander Support Struts

Install De-orbit Motor Simulator

10-11-2

Contingency | Decon

Phase IB Test | De mate

Decon

100% Contingency | Phase II Testing | Install Air Canister & Adapter & Thermal Curtain | Phase II Tests | Inst. Fwd Canister | Phase II Lander Aeroshell Canister/Adapter Integrated Tests | Prepare to Ship

Phase

Decon

Thermal Curtain

LEGEND

EFC = Equipment Functional Check

[ ] = Class 100K Room

Decon = Decontaminate

[ ] = Class 100 Room

10-11-3

β

Aft Cannister

Stringers

Machined Ring

Machined Ring

Thermal Curtain

Corrugations

Aero

S/C Adapter

De-orbit
Motor

Thrusters

Flight Capsule

Fwd Canister

Figure 10-7

10-12 ⌐⟩

Machined Ring

Stringers & Fittings

Gussets

De-orbit Motor Support

Parachute Cannister

Entry Package

Fuel Tank

Surface Lab. Sys.

Hub

Stringers

Lander Assy.

Attenuator

Uni-Disc

Fuel Tanks

Thrusters

Radome

Radar Altimeter

Landing Radar

Imaging Camera

shell

Structural Rings

including feasibility, development, qualification, pre-delivery acceptance and flight acceptance test phases, is to demonstrate the ability of the Flight Capsule to perform to the requirements of the mission. Testing under conditions representative of those to be experienced during the mission provides a realistic evaluation of the performance of the equipment. The VOYAGER Integrated Test Plan is an evolution of the plans employed on the previous Mercury, ASSET, and Gemini spacecraft programs. The arrangement of the test phases and the selection of the test models places emphasis on thorough evaluation tests with attention given to the exclusion of repetitive tests which produce little design improvement or engineering confidence. The test phases are interrelated in that the progress of each phase is a constraint on the subsequent phases. Figure 10-8 presents the time phasing of the required series of tests. Descriptions of each test phase are presented in the following paragraphs.

10.4.1 <u>Feasibility Tests</u> - The purpose of this current test phase is to evaluate materials and design approaches. It has been in progress for the past two years and is to be completed early in Phase C. The results of the tests to date have been used as the foundation for the selection of many aspects of the preferred concept design.

The major portion of the presently completed feasibility testing effort has been devoted to the following:

a. Evaluation of candidate ablative materials

b. Martian surface environment simulation

c. Microbiological research and related investigation of sterilization problems and techniques

d. Soft and hard landing concepts evaluation

e. Structural design evaluation

f. Telecommunications entry and surface characteristics

g. Long term hard vacuum exposure effects

h. Real time versus reduced time test

i. Effects of chemical and heat sterilization on propellants and materials exposed to propellants

Figure 10-9 shows the scope and duration of the feasibility test to date.

10.4.2 <u>Subsystem Tests - Development and Qualification</u> - The subsystem development tests are programmed to provide design information, analysis verification, and a demonstration of design adequacy early in the program. Subsystem qualifica-

10-13

VOYAGER CAPSULE BUS INTEGRATED TEST PLAN — SUMMARY

Test Phase	1967	1968	1969	1970	1971	1972	1973
Feasibility	▬▬	▬					
Development		▬	▬▬▬▬	▬▬			
Qualification				▬	▬▬	Life Test →	
Earth Re-entry Vehicle				▬	▬▬		
Proof Test Model					▬	▬▬▬	
Flight Acceptance					▬	▬▬▬	▬

FEASIBILITY TEST PROGRAM
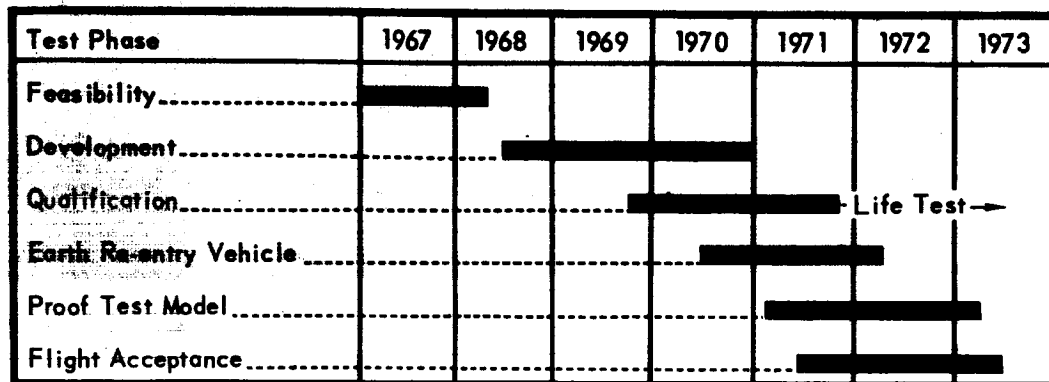
TEST APPLICABILITY			SECTION NUMBER	ACTIVITY
ESP	SLS	CBS		
			1.1.1	**MATERIALS EVALUATION**
		X	1.1.1.1	Ablative Material Tests in Simulated Martian Entry Environments
		X	1.1.1.2	Effect of Sterilization and Vacuum Environments on Ablative Materials
		X	1.1.1.3	Ablative Material Weight Loss in a High Vacuum
	X	X	1.1.1.4	Effect of Time at Elevated Temperature on Energy Absorption Materials
	X	X	1.1.1.5	Evaluation of ORPEAM and Balsa-Cube Binder
	X	X	1.1.1.6	Lockalloy Mechanical Properties Test
	X	X	1.1.1.7	Effect of Sterilization on Resistance Welded Titanium
X	X	X	1.1.1.8	Long Term Material Exposure (ETO, Heat, Vacuum)
X	X	X	1.1.1.9	Accelerated Testing of Materials
		X	1.1.1.10	Heat Shield Materials Evaluation Program
			1.1.2	**STRUCTURAL DESIGN EVALUATION**
		X	1.1.2.1	Entry Cone Structural Panel Fabrication and Ablator Evaluation
		X	1.1.2.2	Static Test of Titanium Panels for Effect of Load on Ablator Bond
		X	1.1.2.3	Static Test to Determine the Buckling Strength of Rings in 120° Conical Shapes
			1.1.3	**LANDING SYSTEMS EVALUATION**
	X	X	1.1.3.1	Sphere Penetration in Sand and Dust
		X	1.1.3.2	Erection Test of ¼ Scale Spherical Lander Model
		X	1.1.3.3	Deflection and Profile Tests on Flexible Inflated Torus Tank
		X	1.1.3.4	Drop Tests of ¼ Scale Torus Lander
		X	1.1.3.5	Overturning-Stability and Drop Tests of 1/10 Scale Legged Landers
		X	1.1.3.6	Determination of Stability of 1/10 Scale Uni-Disc Lander
		X	1.1.3.7	Development of Dynamic Impact Facility for Testing Energy Absorption Materials
		X	1.1.3.8	Static and Dynamic Energy Absorption Capabilities of Balsa Wood, Fiberglass Honeycomb, Aluminum Flexcore and Aluminum Crosscore Before and After Sterilization
			1.1.4	**AERODYNAMICS**
X		X	1.1.4.1	Entry Capsule Force and Moment Tests in Polysonic Wind Tunnel
X		X	1.1.4.2	Aerodynamic Decelerator Static Force and Moment Test in Trisonic Wind Tunnel

Schedule timeline columns: 1965 (A S O N D), 1966 (J F M A M J J A S O N D), 1967 (J F M A M J J A S), numbered 1–26.

Figure 10–9

10–15 ~ *1*

No.	Task			
TELECOMMUNICATION 1.1.5				
1.1.5.1	Antenna Breakdown Tests in Simulated Martian Atmospheres	X	X	X
1.1.5.2	S-Band Antenna Radiation Pattern Tests	X	X	X
1.1.5.3	Flow Field Seeding for Entry Ionization Suppression	X		X
1.1.5.4	Bit Synchronization in a Multipath Environment	X		X
1.1.5.5	RF Systems Multipaction Tests	X	X	X
1.1.5.6	RF Transmissibility Test	X	X	X
1.1.5.7	UHF Antenna Systems Radiation Pattern Tests	X	X	X
PROPULSION 1.1.6				
1.1.6.1	Feasibility of Sterilizing Liquid Propellant Systems	X		
1.1.6.2	Material Compatibility During Sterilization of Anhydrous Hydrazine (N_2H_4)	X	X	
1.1.6.3	Evaluation of Sterilization Effects on Mono-Propellant Engine Performance	X	X	
PYROTECHNICS 1.1.7				
1.1.7.1	Effect of Sterilization and Long Storage Life on Pyrotechnic Actuation Devices	X	X	X
SURFACE ENVIRONMENT SIMULATION AND THERMAL CONTROL EVALUATION 1.1.8				
1.1.8.1	Development of a Martian Environmental Simulation Facility	X	X	
1.1.8.2	Dust Particle Behavior in a Simulated Martian Atmosphere	X	X	
1.1.8.3	Behavior and Characteristics of Simulated Martian Sand and Dust Storms	X	X	
1.1.8.4	Wind Blown Sand and Dust Tests	X	X	
1.1.8.5	Effect of Voyager Mission Requirements on Thermal Control Coatings	X	X	
1.1.8.6	ETO Effects on Thermal Control Coatings	X	X	
1.1.8.7	Heat Pipe Demonstration	X	X	
1.1.8.8	Heat Pipe Control Valve Test	X	X	
1.1.8.9	Measurement of Wind Velocity at Low Pressure	X	X	X
1.1.8.10	Investigation of Martian Surface Phenomena	X	X	
RELIABILITY 1.1.9				
1.1.9.1	Environmental Effects on Electronic Parts	X	X	X
BIO-CONTAMINATION CONTROL TECHNIQUES EVALUATION 1.1.10				
1.1.10.1	Microbiological Research	X	X	X
1.1.10.2	Sterile Assembly	X	X	X
1.1.10.3	Class 100 Facility Operation	X	X	X
EXPERIMENTAL INVESTIGATION 1.1.11				
1.1.11.1	Large Amplitude Coning in a Single Degree-of-Freedom Gyro	X	X	X
1.1.11.2	Efficiency of Molecular Separators for Interfacing a Gas Chromatograph With a Mass Spectrometer	X	X	
1.1.11.3	Pyrolysis – Gas Chromatograph for Chemical Analysis	X	X	
1.1.11.4	Digitization of Time-of-Flight Mass Spectra	X	X	
1.1.11.5	Advantages of a Multi-Diameter Separation Column in Gas Chromatographic Analysis of Organics	X	X	

tion testing is thus conducted to demonstrate hardware adequacy with margins of performance that are significantly greater than those expected for ground and flight extremes. See Figure 10-10 for the time phasing of the tests. The various subsystem development and qualification tests employ hardware in breadboard, engineering prototype, and manufacturing prototype configurations. Figure 10-11 is a matrix, showing the application of the tests performed on the CBS.

10.4.3 <u>System Test - Development and Qualifcation</u> - Those tests requiring a relatively complete representation of the 1973 flight configuration hardware, procedures, support equipment and other elements needed to achieve the defined test objectives. The design verification tests described are similar to the Pre-Delivery Acceptance (PDA) or Flight Acceptance Tests (FAT) and to each other in flow and form, providing a build-up of training, experience, ability, and confidence in the pre-mission preparations. Figure 10-12 shows the timing and sequence of these tests. Test categories are:

a. **Engineering Model Tests are performed to establish levels of acceptable integrated system and subsystem performance using components of engineering prototype configuration.**

b. Thermal Control Subsystem Tests are performed to verify that the subsystem will properly function in all of the simulated mission environments. All other subsystems are installed using components of manufacturing prototype configuration.

c. **System Life Tests demonstrate systems operations capability, compatibility, and endurance, employing the hardware previously used for the thermal control tests. One of two programs, the simulation mission test, verifies design integrity as regards function and compatibility. The other, systems compatibility and endurance tests, evaluates the time dependency of the physical and functional characteristics of the subsystems; determining the causes and means of degradation as it occurs. These tests are performed by the CBS contractor.**

d. Earth Reentry Vehicle (ERV) Flight Test Program - Isolated subsystems test programs fulfill the minimum flight test qualification requirements. The systems flight test qualification program is considered in the event that the cumulative needs of the Voyager systems justify it.

e. Proof Test Model (PTM) Test is a final qualification system test that uses flight qualifiable hardware. It demonstrates system performance capabilities

CAPSULE BUS
SUBSYSTEMS TEST SCHEDULE

	1968	1969
	J F M A M J J A S O N D	J F M A M J J A S O N D
PHASE C		
PHASE D		
1.0 Material and Processes		
Material Selection		
Fabrication & Assembly Processes		
2.0 Wind Tunnel Model Test		
Capsule		
Aerodynamic Tests		
Thermodynamic Tests		
Structural Dynamic Tests		
Lander		
Aerodynamic Tests		
Thermodynamic Test		
Capsule–Lander		
Aerodynamic Tests		
Parachute		
Aerodynamic Tests		
3.0 Aerodynamic Decelerator Tests		
Development Testing		
Configuration Refinement		
Wind Tunnel Model Tests		
Balloon Tests (8)		
Component Development Tests		
Subsystem Design Verification		
Ground Operational Check		
Helicopter Drop Test (5)		
Aircraft Drop Tests (10)		
Balloon Launched Tests (8)		
Qualification Testing		
Components		
Subsystem–Balloon Launched Tests (10)		
4.0 Thermal Control Subsystem		
Development Testing		
Multi-Layer Insulation Blanket Test		
Heater & Thermostat Assemblies Evaluation		
Thermal Control Coatings Test		
Thermal Control Simulator Test		
Qualification Testing		
Heaters & Thermostats		
5.0 Structural/Mechanical Subsystem		
Structural Tests		
Development Testing		
Canister Structural Segments Test		
Structural Element Test		
Complex Structural Segments Test		

Figure 10–10

10-17–1

1970	1971	1972
J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D

10-17-2

	1968	1969
	J F M A M J J A S O N D	J F M A J J A O N

PHASE C

PHASE D

5.0 Structural/Mechanical Subsystem (Continued)

    Qualification Testing – Static Tests (Static Art No. 1)

        Sterilization Canister

        Capsule Adapter

        Aeroshell

        De-Orbit Motor Adapter

        Flight Capsule

    Entry Heat Shield, Non-Ablative Nose Cap

        Development Testing

        Qualification Testing

    Entry Heat Shield, Ablative

        Development Testing

        Qualification Testing

    Landing Attenuator Development Tests

        Development Tests

            Scale Model Drop Tests

            Energy Absorption Material – Element Tests

            Full Scale Static Tests

            Dynamic Drop Tests

        Qualification Tests

            Dynamic Drop Tests (Static Art No. 2)

    Canister Pneumatic Subsystem

        Development Testing

            ETO & Heat Sterilization Evaluation

            Component Functional Evaluation

            Subsystem Ascent Simulation

        Qualification Testing

            Components

            Subsystem

6.0 Propulsion Subsystems

    6.1 Reaction Control Subsystem

        Subsystem Development Tests

            Engines

            Propellant Tanks

            Other Components

            Pressurant & Propellant Storage Test

        Subsystem Evaluation

            Subassembly Performance Test

            Chemical/Heat Sterilization

            Subsystem Performance Test

            Dynamic Load Test

        Qualification Testing

            Components

            Subsystem

        Reaction Control Dynamic Test

Figure 10–10 (Continued)

10–18

A Gantt/schedule chart spanning the years 1970, 1971, and 1972, with monthly columns labeled D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D.

CAPSULE BUS
SUBSYSTEM TEST SCHEDULE (Continued)

	1968												1969										
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

PHASE C ----------

PHASE D ----------

6.0 Propulsion Subsystems (Continued)

  6.2 Terminal Propulsion Subsystem
    Subsystem Development Tests
      Engines---------
      Tank---------
      Other Components---------
      Pressurant & Propellant Storage Test---------
    Subsystem Evaluation
      Subassembly Performance Test---------
      Chemical/Heat Sterilization---------
      Subsystem Performance Test---------
      Dynamic Load Test---------
    Qualification Testing
      Components---------
      Subsystem---------
  6.3 De-Orbit Motor
    Component Development
      Propellant---------
      Case---------
      Nozzle---------
    Subassembly Development
      Igniter---------
      Thrust Termination---------
    Subsystem (Prototype) Evaluation Test---------
    Qualification Testing
      Subsystem---------

7.0 Pyrotechnic Subsystems
  Development Testing
    Explosive & Pyrotechnic Composition
      Post Sterilization Evaluation---------
    Pyrotechnic Assembly Development
    Testing (1)---------
      Ambient Performance
      Post Sterilization Performance
      Performance Margins
      Proof Pressure Tests
      Burst Pressure Test
      Hi-Low Operating Temp. Performance
    Prototype Performance Test---------
  Qualification Testing
    Subsystem---------

Figure 10-10 (Continued)

10-19 -1

CAPSULE BUS
SUBSYSTEMS TEST SCHEDULE (Continued)

	1968	1969
	J F M A M J J A S O N D	J F M A M J J A S O N D
PHASE C		
PHASE D		
8.0 Typical Development Test For Electronic Subsystems		
Breadboard Testing ①		
Performance		
Performance (Temp & Pwr Extremes)		
Trial Sterilization Cycles		
Performance Margin Tests		
EMI Search Test		
Selected Mission Environments		
Engineering Prototype Testing ①		
Performance Acceptance		
Performance – Sterilization Cycles		
Performance Margin Test		
Performance – Selected Mission Environments		
EMI Margin Test		
Integrated Electronic Subsystems Bench Testing ①		
Power Up Testing & Systems Operation		
Interface Verification Tests		
EMI Margin Test		
Performance Margin Tests		
In Flight Checkout		
Qualification Testing ①		
Manufacturing Prototype Hardware		
Performance–Acceptance		
Performance–Sterilization Cycles		
Performance–Margin Test		
Performance–Mission Environments		
Performance–Mission Life Test		
9.0 Cabling Subsystem Development Test		
Component Evaluation		
Electrical Interface Disconnect (CBS/SLS) Design Evaluation		
Prototype Wire Bundles Functional Evaluation		

① The following tests are included in the testing.

Figure 10–10 (Continued)

10–20 – *J*

	1970	1971	1972
	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D

10-20-2

FLIGHT CAPSULE TEST MATRIX

TEST TITLE	SECTION NUMBER	CAPSULE BUS SYSTEM	SURFACE LABORATORY SYSTEM	ENTRY SCIENCE PACKAGE
Material Tests	1.2.1	X	X	X
Wind Tunnel Tests	1.2.2	X		
Aerodynamic Decelerator Tests	1.2.3	X		
Thermal Control Subsystem	1.2.4			
Thermal Control Blankets	1.2.4.1	X	X	X
Heaters & Thermostats	1.2.4.2	X	X	X
Thermal Coatings	1.2.4.3	X	X	X
Heat Pipes	1.2.4.4		X	
Thermal Control Simulator	1.2.4.4	X	X	X
Structural/Mechanical Subsystems	1.2.5			
Structural Tests	1.2.5.1	X	X	X
Mechanical Devices	1.2.5.2		X	
Dynamic Tests	1.2.5.3	X	X	X
Heat Shield Tests	1.2.5.4	X		
Canister Pneumatic Tests	1.2.5.5	X		
Propulsion Subsystems	1.2.6			
Reaction Control	1.2.6.1	X		
Terminal Propulsion	1.2.6.2	X		
De-orbit Motor	1.2.6.3	X		
Pyrotechnic Tests	1.2.7	X	X	
Electronic Subsystems	1.2.8			
Guidance & Control		X		
Power		X	X	X
Antenna		X	X	X
Radio		X	X	X
Telemetry		X	X	X
Data Storage		X	X	X
Guidance Sensor		X		
Command		X	X	
Control (Antenna Steering)			X	
Sequencer		X	X	
Science Subsystem Test	1.2.9		X	X
Cabling Subsystem Test	1.2.10	X	X	X

Figure 10—11

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FLIGHT CAPSULE SYSTEM TEST SCHEDULE (DEV & QUAL)
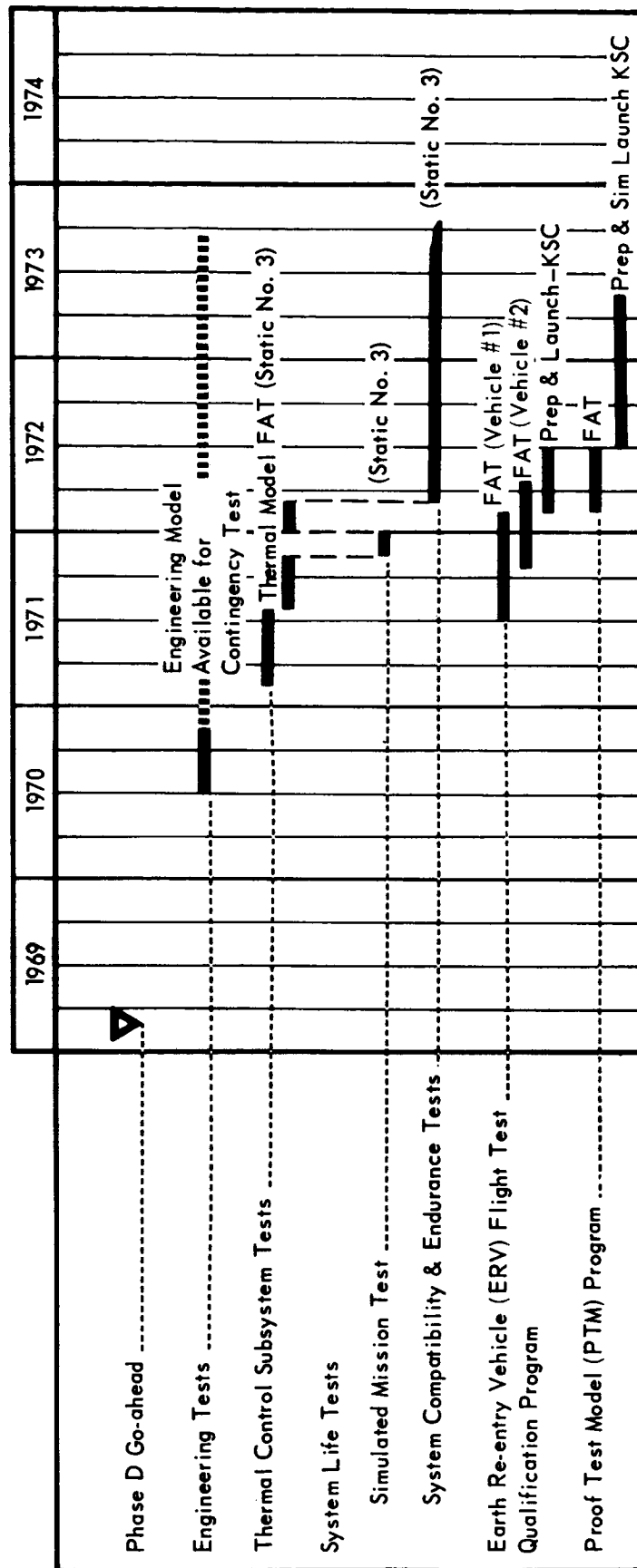
and OSE compatibility, verifies flight hardware test procedures, and provides test organization training. From module testing to simulated launch, the PTM is tested within the Flight Acceptance Test format to qualification level standards and parameters.

10.4.4 <u>Flight Acceptance Tests</u> - These tests are conducted on each Flight Capsule to demonstrate the capability of the system to perform in accordance with the mission requirements. The Flight Acceptance Test (FAT) Plan presented by Figure 10-13 establishes the sequence of tests and periods of preparation necessary to assure "mission readiness" at the time of launch. It is based upon the minimum amount of disassembly required and the exclusion of repetitive tests which produce little system improvement or engineering confidence.

Commonality of the test procedures and equipment at the SLS and ESP facilities, the Capsule Bus facility, and the launch site minimizes rejection of equipment due to variations in test configuration. Test descriptions are on Figure 10-14

This test plan reflects McDonnell's "factory-to-pad" policy - the delivery of a Flight Capsule to the launch site in a "flight ready" condition requiring only servicing and integration with the other elements of the space vehicle and ensuring an efficient launch site preparation program. This "factory-to-pad" approach makes maximum utilization of the contractor capabilities possible and ensures a high level of confidence in mission success.

The FAT test teams are comprised of on the personnel most knowledgeable about the Flight Capsule. These personnel are assigned from three sources; 1) the Project Design Group, 2) the in-plant test operations group, and 3) the launch site operations group. Each of these groups is nearing the end of design effort, equipment and in-plant checkout procedures preparation, or launch site facility tests requirements and preparation. The assignment of equal ratios of personnel from these areas provides a balanced group with a high degree of versatility. Teams are assigned and perform the tests on the PTM and each of the four Flight Capsules from the initial in-plant tests until the time of launch. Three teams are anticipated to handle the five vehicles.

Subsystems specialists from the launch teams are assigned to support NASA in monitoring Flight Capsule performance throughout the mission.

10.5 <u>Element Plans</u> - Those implementation elements plans not previously discussed in this section are:

    a. <u>Design Engineering</u> - The preferred concept has been selected to provide

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FLIGHT ACCEPTANCE TEST PLAN

HARDWARE RECEIVING INSPECTION AND ACCEPTANCE	PHASE IA	PHASE IB	
	MODULE TESTS	SUBSYSTEM TESTS	CAPS (INTE

McDonnell Douglas Corp.

Receiving Inspection

Parts/Subassembly Assembly Buildup and EFC

(Class 100,000 Clean Room)

Capsule Lander

- Voltage Standing Wave Ratio (VSWR)
- Electrical Power Circuit Integrity
- Electrical Power
- Telemetry (TM)
- Sequential
- Thermal Control
- Radio and Antennas
- Guidance and Control
- Radar
- Propulsion
- Structures and Mechanisms
- Surface Laboratory and ESP
- Wt, Balance and Alignments
- Mars Atmosphere

Ship Capsule to KSC CAF
Mate Capsule Lander and Aeros
Weight and Balance
Alignment of De-Orbiter T
De-Orbiter Simulator In
VSWR
Electrical Power
Capsule Land
Structure a
ETO and
into Cla

Post
M

Aeroshell Assembly

- VSWR
- Electrical Power Circuit Integrity
- Electrical Power
- TM
- Propulsion (RCS)
- Scientific Experiments
- Structures

Mate Adapter and Sterilization Canister
Weight and Balance
De-Mate Adapter and Canister

Adapter

- Electrical Power Circuit Integrity
- Electrical Power
- TM
- Structures

Sterilization Canister

- Electrical Power Circuit Integrity
- Electrical Power
- TM
- Structures

←————————Class 100,000 Area————————→

ABBREVIATIONS

CAF	– Capsule Assembly and Test Facility
Capsule	– Flight Capsule
DSIF	– Deep Space Instrumentation Facility
EFC	– Equipment Functional Checks
JFACT	– Joint Flight Acceptance Composite Test
JCLOT	– Joint Closed-Loop Operations Tests
KSC	– John F. Kennedy Space Center
LV	– Launch Vehicle
McDonnell	– McDonnell Douglas Corp.
SCF	– Spacecraft Checkout Facility
PV	– Planetary Vehicle (Flight Capsule & Flight Spacecraft)
RCS	– Reaction Control System
SV	– Space Vehicle (PV & LV)

Figure 10–13

10–24

PHASE II	PHASE III		PHASE IV
ULE SYSTEM TESTS GRATED SUBSYSTEMS)	KSC INDUSTRIAL AREA	CAPSULE ASSEMBLY & TEST FACILITY (CAF) (EXPLOSIVE SAFE AREA ESA)	KSC LAUNCH PAD 39

Disassembly/Assembly Area
ell Assembly
ol
stallation

Circuit Integrity
er/Aeroshell Interface Test
nd Mechanism
Heat Cycle Prior to Entry
ss 100 Area

Capsule Receiving Inspection
Capsule System Assurance

Preparation for Sterilization–Final Check on SLS Extendible Devices
Move Capsule to Servicing Area
Servicing for Flight
Move Capsule to Sterilization Area
Terminal Sterilization
Move Capsule to Disassembly Assembly Area
Flight Capsule Weight
Capsule System Assurance
Move Capsule to PV Assembly Area
Final Capsule – Spacecraft Mate
PV System Confidence
PV – DSIF 71 Compatibility (JCLOT)
PV Weight – Balance
Move PV to Holding Area
PV Storage & Monitoring
Move PV to PV Assembly Area
Final CAF PV Systems Confidence
Final CAF PV Inspection – Enshroud
Move PV to Pad
PV–LV Mate
PV Systems Verification
SV Flight Readiness Test (JFACT)
SV Countdown Demonstration Test
Launch Countdown
Mission Support

Heat System Verification–Check SLS Extendible Devices
te Capsule Lander/Aeroshell with Adapter and Canister Base
System Assurance
Simulated Mission with Spacecraft Simulator
Capsule Servicing
Sterilization Canister Installation
Vibration
Post Vibration
Preparation for Space Simulation Test
Launch-Cruise Configuration Environmental
Post-Space Environment Test
Capsule Deservicing
Shipment Preparation

Move Capsule to PV Assembly Area
Capsule – Spacecraft Mate
PV Electrical Power Circuit Integrity
PV Systems Assurance
PV Simulated Mission – DSIF 71 Compatibility
PV–LV Simulator Mate
Simulated SV Systems Assurance
PV–LV Simulator Demate
Capsule – Spacecraft Demate
Capsule – Spacecraft RF Compatibility
Move Capsule to Disassembly Assembly Area

—Class 100 Area——————|——| |—Class 100—|

Class 100

10-24-2

FLIGHT ACCEPTANCE TEST PLAN

PHASE	TEST NO. AND TITLE	OBJECTIVE
1A	1. Voltage Standing Wave Ratio (VSWR)	To evaluate the characteristics of the RF paths within the Capsule Bus prior to energizing the Radio and Antenna Subsystems. Insertion loss measurements, VSWR values and antenna phasing characteristics are recorded for future reference.
	2. Electrical Power Circuit Ground Integrity	To verify that the Power Subsystem is correctly connected and that it is safe to energize the Capsule Bus in the next test. Fuses are checked and tests performed to verify that no circuits are shorted to ground. Stray voltage and shield continuity tests are performed on the pyrotechnic circuits.
	3. Electrical Power	To verify prime power distribution, check buses and power subsystems control devices with the Power Subsystem energized. To perform stray voltage tests on the pyrotechnic circuits in an energized environment. To verify the ability of the Subsystem Test Equipment (SSTE) to control the application and removal of power to the Capsule Bus. This test verifies that it is safe to energize the other subsystems.
	4. Telemetry (TM)	To evaluate the basic subsystem capability to monitor voltage, pressure, temperature, and other condition indicators. To verify that the SSTE provides satisfactory monitoring operation. This test provides assurance that the other subsystems have TM monitor support when they are energized.
	5. Sequential	To verify proper operation of sequencing devices and check timing functions. To check pyrotechnic circuitry by means of squib simulators connected in place of the pyrotechnic devices. To evaluate redundant and back-up circuits. This test verifies proper operation of the Sequencer Subsystem prior to energizing the other subsystems.
	6. Thermal Control	To verify satisfactory operation of the Thermal Control Subsystem. To check that portion of the subsystem which can be operated with only the Power and Telemetry Subsystems in operation. Verify integrity and operation of Thermal Control Subsystems prior to energizing the remaining subsystems.
	7. Radio and Antenna	To evaluate the performance of the Radio and Antenna Subsystem with power applied to the transmitters, antennas, and subsystem control devices. To evaluate signal strength, phase characteristics, power division and subsystem performance. Record values of measurements to be used as reference data in subsequent tests.
	8. Guidance and Control	To operate and evaluate the G and C subsystem. To verify proper power regulation (AC and DC) of the power supply, performance of the Inertial Measuring Unit (IMU), and the operation of the Guidance and Control Computer.
	9. Radar	To verify the ability of the Landing Radar to measure range and rate. To operate the Radar Altimeter and verify that the sequence of operation is correct and that the timing is accurate.
	10. Propulsion	To verify the integrity and operation of the propulsion subsystem. To leak check gas and liquid portions of the subsystems. To check pressure regulation, operation of transducers, and proper signals to the thrusters from the G & C electronics.
	11. Structures and Mechanisms	To verify that all mechanical devices operate properly and that the design clearances with structure are maintained.
	12. Surface Laboratory and Entry Science Package	To integrate the SLS and ESP with the Capsule Bus and verify proper operation. Perform pre-launch, cruise and pre-separation checkout to evaluate condition of experiments prior to deployment. Deploy experiments in mission sequence to verify electrical and mechanical operation.
	13. Weight, Balance and Alignment	To determine the actual weight and C.G. location. Alignment checks are performed on the IMU, the S-band antenna and other extendible devices in the SLS.
1A	14. Mars Atmosphere	To verify the operation of the SLS when subjected to a simulated Mars atmosphere. The Lander subsystems are not energized. The SLS is energized and the extendible devices deployed in mission sequence to verify that the system operates satisfactorily.

Figure 10-14

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	Item	Description
IB	15. Mate Capsule Lander and Aeroshell Assembly	To prepare for interface test.
	16. Weight and Balance	To determine the actual weight and Center of Gravity (C.G.) location of the Flight Capsule.
	17. Alignment of De-Orbiter Tool	To adjust the De-Orbiter Motor support links.
	18. De-Orbiter Simulator Installation	To install a Simulator representative of the flight article with weight, C.G. and physical configuration.
	19. Voltage Standing Wave Ratio (VSWR)	This test insures that the co-axial cables between the Capsule Lander and Aeroshell are satisfactorily engaged. This also permits end to end insertion loss measurements.
	20. Electrical Power Circuit Integrity	To verify that the mating of the Capsule Lander and Aeroshell did not cause a bus short to ground. The Pyrotechnic circuits shield continuity across the interface also are verified. To verify that multipath ground circuits do not exist.
	21. Capsule Lander/Aeroshell Interface Test	To verify all interface functions between the Capsule Lander and Aeroshell. Evaluate all subsystems operation for interaction between subsystems. Perform simulated mission to observe operating characteristics of the Capsule Bus.
	22. Structure and Mechanisms	To verify that all mechanical devices operate properly and that design clearances with structure are maintained. To verify that the proper clearance between the Capsule Lander and Aeroshell is maintained to assure satisfactory separation during the mission. Install squib simulators for subsequent tests.
	23. ETO and Heat Cycle	To decontaminate prior to entry into the Class 100 clean room.
IB	24. Post Heat Cycle System Verification (Capsule Lander 'Aeroshell)	To verify proper operation of all subsystems after exposure to Ethylene Oxide (ETO) and heat cycle. The test is essentially a repeat of the Capsule Lander/Aeroshell interface test performed just prior to entry in the Class 100 Clear Room. Additional tests are performed by partially extending the SLS devices to provide assurance that they operate after being subjected to the heat cycle.
II	25. Mate Capsule Lander Aeroshell with Adapter and Canister Base	To prepare for test of total system.
	26. System Assurance	To verify the satisfactory operation of all subsystems after mating the Capsule Lander 'Aeroshell with the Adapter and Canister Base section. This is an integrated test of all subsystems except that portion which is contained in the removable Canister section.
	27. Simulated Mission (with Spacecraft Simulator)	To verify proper operation of all subsystems throughout a simulated mission. The sequence and timing of controlled functions is verified. The Flight Capsule/Spacecraft interface functions are verified by use of the Spacecraft simulator. The checkout is similar to that experienced in the launch and mission phases.

FLIGHT ACCEPTANCE TEST PLAN (Continued)

PHASE	TEST NO. AND TITLE	OBJECTIVE
	28. Flight Capsule Servicing	This is a preparation period rather than a test. The Flight Capsule is serviced with inert mediums to provide a condition as representative as possible to that which exists during the launch phase. Squib simulators are installed to represent the flight pyrotechnic devices to be verified after the Vibration Test. Test batteries are installed during this servicing period.
	29. Sterilization Canister Installation	To install forward Canister assembly.
	30. Vibration	The test demonstrates the ability of the Flight Capsule to withstand the loads imposed by simulated launch phase vibration. Those subsystems which are operating during the launch phase are energized. Exitation is applied along horizontal axis and the vertical axes.
	31. Post Vibration Test	To verify that there has been no system degradation. All subsystems are energized and the integrity of the squib simulators are verified by use of the OSE connector.
	32. Preparation for Space Simulation Test	To prepare the Flight Capsule and Space Chamber for test.
	33. Launch Cruise Configuration Environmental Test	To verify that the Flight Capsule operates satisfactorily under simulated flight environment.
	34. Post-Space Environment Test	To verify that there has been no system degradation.
	35. Capsule Deservicing	To deservice the Flight Capsule in preparation for delivery to the launch site. The forward Canister is removed and the inert mediums deserviced. The test batteries and squib simulators are removed at the launch site upon the installation of the flight units. This eliminates an unnecessary disassembly and assembly cycle.
II	36. Shipment Preparation	This is also a preparation period. The forward Canister is installed and the Flight Capsule charged with dry nitrogen to maintain a positive pressure within the Canister until the arrival at the launch site Class 100 room.
III	37. Capsule Receiving Inspection	To verify no damage was incurred in shipment.
	38. Capsule System Assurance	This test verifies the operation of the Capsule Bus after shipping and demonstrates the operational and Electro-Mechanical (EM) compatibility of the Flight Capsule and the System Test Complex (STC) at the launch site.
	39. Capsule – Spacecraft Mate	To prepare for test.
	40. PV Electrical Power Circuit Integrity	To verify that no multiple ground paths exist between the Flight Capsule and the Spacecraft.
	41. PV Systems Assurance	To verify the Flight Capsule/Spacecraft compatibility. To demonstrate that the PV operates with no subsystem interaction between the assemblies.
	42. PV Simulated Mission – Deep Space Instrumentation Facility (DSIF-71) Compatibility	To demonstrate the performance of the PV throughout the terminal launch count and an abbreviated mission. Demonstrate the capability of the DSIF to transmit to the Spacecraft and the relay of the commands to the Flight Capsule.
	43. PV-LV Simulator Mate	To prepare for test.
	44. Simulated Space Vehicle	To demonstrate operation of the Flight Capsule system with the other elements of the Space Vehicle. This

Figure 10–14 (Continued)

	Systems Assurance	
		test verifies the compatibility of the Space Vehicle with all systems in operation. The Launch Vehicle simulator provides the L/V functions.
	45. PV–LV Simulator Demate	To prepare for test.
	46. Capsule – Spacecraft Demate	To prepare for test.
	47. Capsule – Spacecraft RF Compatibility	To demonstrate the capability to transmit and receive between the Capsule and the Spacecraft when physically separated.
	48. Preparation for Sterilization-Final Check on SLS Extendables	The forward Canister is removed in preparation for sterilization. The squib simulators, batteries, and de-orbiter simulator installed in-plant for the Vibration Test are removed. The SLS is energized and the final operational check on the extendable devices (particularly the S-band antenna) are performed.
	49. Servicing for Flight	To install flight batteries, flight pyrotechnics and service the propulsion subsystems.
	50. Terminal Sterilization	To decontaminate the Flight Capsules.
	51. Flight Capsule Weight	To determine actual weight after servicing.
	52. Flight Capsule System Assurance (Post Sterilization)	To demonstrate that the Flight Capsule system performs satisfactorily after the terminal sterilization.
III	53. Final Capsule – Spacecraft Mate	To prepare for flight.
IV	54. PV Systems Confidence	To verify the proper operation of the PV with the Flight Capsule and Spacecraft mated for flight.
	55. PV DSIF–71 Compatibility	To verify compatibility of operation of the PV and the DSIF. This is the final check of this interface before going to the pad.
	56. PV Weight and Balance	To determine weight and C.G. location.
	57. Final CAF PV Systems Confidence	To verify satisfactory operation of PV prior to installation the shroud.
	58. Final CAF PV Inspection – Enshroud	To prepare for move to the Launch Pad.
	59. PV–LV Mate	To prepare for Pad tests.
	60. PV Systems Verification	To demonstrate the satisfactory operation of the PV System on the pad. To verify the proper connection of the launch site OSE with the PV and satisfactory operation of the STC.
	61. SV Flight Readiness Test	This test demonstrates the operation of all elements of the SV (PV and LV). The PV–LV interface connection is verified in this test.
	62. SV Countdown Demonstration Test (CDDT)	This is a dress rehearsal of the launch countdown. This test verifies that the precise phasing of preparations, servicing, testing, removal of the MSS and all operational elements of the launch are in a ready state.
IV	63. Launch Countdown	To perform final tests and launch the SV.

mission success and the major engineering milestones necessary to implement this concept are incorporated on the master schedule.

b. <u>Quality Assurance Plan</u> - This plan ensures the compliance of the flight article with the design requirements. Experience in stringent operational requirements on previous space programs is the basis for this plan.

c. <u>Procurement Plan</u> - The objective of this plan is to provide products on time and with the required technical excellence at the lowest cost. The selection of suppliers is based on maximum use of experience on related products.

d. <u>Science Integration</u> - The Science Subsystem requires special emphasis. Experience on previous programs has shown that experiments are often the critical path. Interface definitions, test objectives, equipment qualification and delivery requirements consistent with those of the Flight Capsule are required.

e. <u>Electromagnetic Compatibility (EMC)</u> - Design and test requirements have been established to ensure electromagnetic compatibility within the Flight Capsule, and with the Spacecraft, Launch Vehicle, Launch Complex, and the Operational Support Equipment.

f. <u>Sterilization Plan</u> - This plan defines the controls required to assure observance of the Planetary Quarantine.

g. <u>Reliability Plan</u> - The control techniques and procedures to provide Reliability Assurance throughout the program have been prepared based upon the preferred concept.

h. <u>Interface Control</u> - This control plan encompasses VOYAGER System-To-System interfaces versus McDonnell responsibility, use and control of formal specifications, organization, and schedule requirements for the Voyager Flight Capsule.

i. <u>Parts, Materials and Processes Plan</u> - This plan describes the Project level activity regarding selection, and control of parts, materials and processes applied to the VOYAGER Flight Capsule.

j. <u>Operational Support Equipment (OSE) Implementation</u> - Outlines policies, procedures, and scope of management and implementation effort required to design, procure, fabricate, test, install, and validate OSE.

k. <u>Logistics Support</u> - Provides the logistics direction and control that assure facilities, personnel, and equipment capable of performing the programmed tests and operational mission.

10-27

1. <u>Facilities</u> – Identifies the overall Flight Capsule facilities requirements.

m. <u>Project-Hardware Accountability/Traceability and History (PATH) Systems</u> – Provides basic requirements, procedures, and operations of data information systems (manual and automated).

n. <u>Safety</u> – Describes the safety organization, planning and procedures for in-plant and remote sites.

o. <u>Training</u> – Provides in-plant training requirements (sterilization procedures, equipment and system familiarization, and personnel proficiency evaluation).

p. <u>Project Control</u> – Describes the integrated use of the work breakdown structure, PERT, schedule interface log, cost/performance analysis, and project communication center.

q. <u>Data Management</u> – Highlights the methods for establishing data requirements and the techniques for controlling and disseminating this data.

r. <u>Configuration Management</u> – Defines the approach for establishing the various configuration baselines and the means by which changes to these baselines will be controlled.

SECTION 11

UTILIZATION FOR FUTURE MISSIONS

The VOYAGER mission goals will change throughout the 1970's as the environment is better understood and as the results of the early missions are evaluated. Since it is difficult (really impossible) to predict these changes, a system design incorporating a large degree of flexibility will have a substantial, though hard to quantify, advantage.

Each Capsule Bus subsystem reacts differently to mission goal modifications. Analysis of subsystem sensitivity has identified those that could be standardized, however, for use during several launch opportunities. The use of standarized subsystems may degrade performance for individual missions, but the potential reduction in program costs and increase in reliability and operational flexibility must be considered.

The two major influences on Capsule Bus requirements for future missions are increasing Surface Laboratory weight and decreasing environmental uncertainty. The primary effect on the Capsule Bus System is the greater payload weight, which implies greater entry weight and increased entry body ballistic parameter. The introduction of RTG electrical power sources and changing payload characteristics, such as mobility, also affects some subsystems. Figure 11-1 tabulates the most critical effects.

In partial relief of the requirements caused by payload growth will be the diminishing need to accept a broad spectrum of environmental uncertainty. The design of a weight-efficient Mars Capsule is currently hindered by gross uncertainties of the natural environment. Effective use of data from early missions will allow substantial increases in design and operational efficiency. However, due to lead time requirements these data cannot significantly affect the design of subsystems earlier than two launch opportunities after receipt. The data which will significantly affect each type of subsystem are indicated in Figure 11-2.

The most immediate effect of improved environment definition will be on the operational capability of the capsules launched in the next following opportunity. Data from early opportunities will allow operations to be conducted closer to design limits. Capsule design specification, frequently stated in terms of entry corridor or an atmospheric model designation, can be related to specific air loads, thermal loads, communication geometry, sequence timing, etc. This is expected to permit either more operational planning flexibility for a given Flight Capsule

11-1

CBS SUBSYSTEM SENSITIVITY TO
MISSION PERFORMANCE

	LANDING WEIGHT	ENTRY WEIGHT	M/CDA	POWER SOURCE	PAYLOAD TYPE	LANDING SITE
Aeroshell Structure			√			
Heat Shield			√			
Sterilization Canister				√		
Adapter		√				
De-orbit Propulsion		√				√
Terminal Propulsion	√				√	
Aerodynamic Decelerator	√	√	√		√	
Lander	√				√	
Reaction Control					√	
Guidance & Control			√			√
Power				√		
Telecommunications						√
Thermal Control				√	√	√

CBS SUBSYSTEM SENSITIVITY TO ENVIRONMENT DEFINITION

SUBSYSTEM	ATMOSPHERIC DATA	SURFACE DATA
Aeroshell Structure	Pressure vs. Altitude	
Heat Shield	Pressure vs. Altitude	
Canister		
Adapter		
De-orbit Propulsion		
Aerodynamic Decelerator	Density vs. Altitude	
Terminal Propulsion	Density vs. Altitude	Cohesiveness
Landing	Surface Winds, Density	Roughness, Slopes, Bearing Strength
Reaction Control	Low Altitude Winds	
Guidance and Control	Density vs. Altitude	Reflectivity, Roughness, Slopes
Power		
Telecommunications	Ionization Potential	Terrain Features
Thermal Control		

Figure 11-2

11-3

Weight or an increased Flight Capsule Weight with a smaller operational envelope.

11.1 <u>Postulated Future Mission Requirements</u> - The data returned by the 1973 VOYAGER will likely be the first to permit confident reduction of the environmental uncertainties. Figure 11-3 shows that none of the atmosphere-sensitive subsystems could be redesigned on a routine basis for the 1975 launch based on the 1973 data, and that only structural subsystems and heat shield could be modified on a minimum time or "crash" basis. Thus, the 1975 Capsule Bus will be essentially unchanged from 1973.

The 1977 and 1979 requirements will reflect not only the improved environmental definition but the changing payload definition resulting from the results of the early biological experiments (see the exploration strategy discussion in IIIB). For this study, a fully mobile laboratory has been postulated with the following Flight Capsule weight summary:

Flight Capsule weight	7000 lb
Pre-de-orbit weight	6170 lb
Post-de-orbit weight	5500 lb
Entry weight	5390 lb
Aerodynamic decelerator deployment weight	5390 lb
Terminal propulsion initiation weight	4165 lb
Touchdown weight	3500 lb
Surface Laboratory weight	1890 lb

11.2 <u>Capability of Preferred Design</u> - The preferred Capsule Bus system design, discussed previously, has a built-in margin to accept increased payload weight or changing environmental definition. Figure 11-4 shows the effect of the operational variables - entry velocity, V_E, entry angle, γ_E, and the atmosphere - on the growth capability of the Aeroshell structure as measured by the dynamic pressure. The 1973 capsule (except the parachute) is designed for an M/C_DA of 0.3 slugs/ft^2 entering a VM-8 atmosphere at 15,000 ft/sec and a -20° entry angle. The actual M/C_DA of the preferred concept, and the parachute design value, is 0.266 slugs/ft^2. The 7,000 pound 1979 Capsule will have an entry M/C_DA of about 0.45 slugs/ft^2. In order not to exceed the design value of dynamic pressure, the 1979 operational entry angle must be kept below -16° for V_E=15,000 ft/sec or -17.7° for V_E=13,000 ft/sec, for the critical VM-8 atmosphere. The primary atmospheric variable is the scale height, H_ρ. If by 1979 the Martian atmosphere, through better definition, is expected to have a H_ρ of no less than 7.2km, a -20° entry angle can be tolerated for V_E=15,000 ft/sec.

SUBSYSTEM DESIGN LEAD TIME REQUIREMENTS

Weeks Before Launch
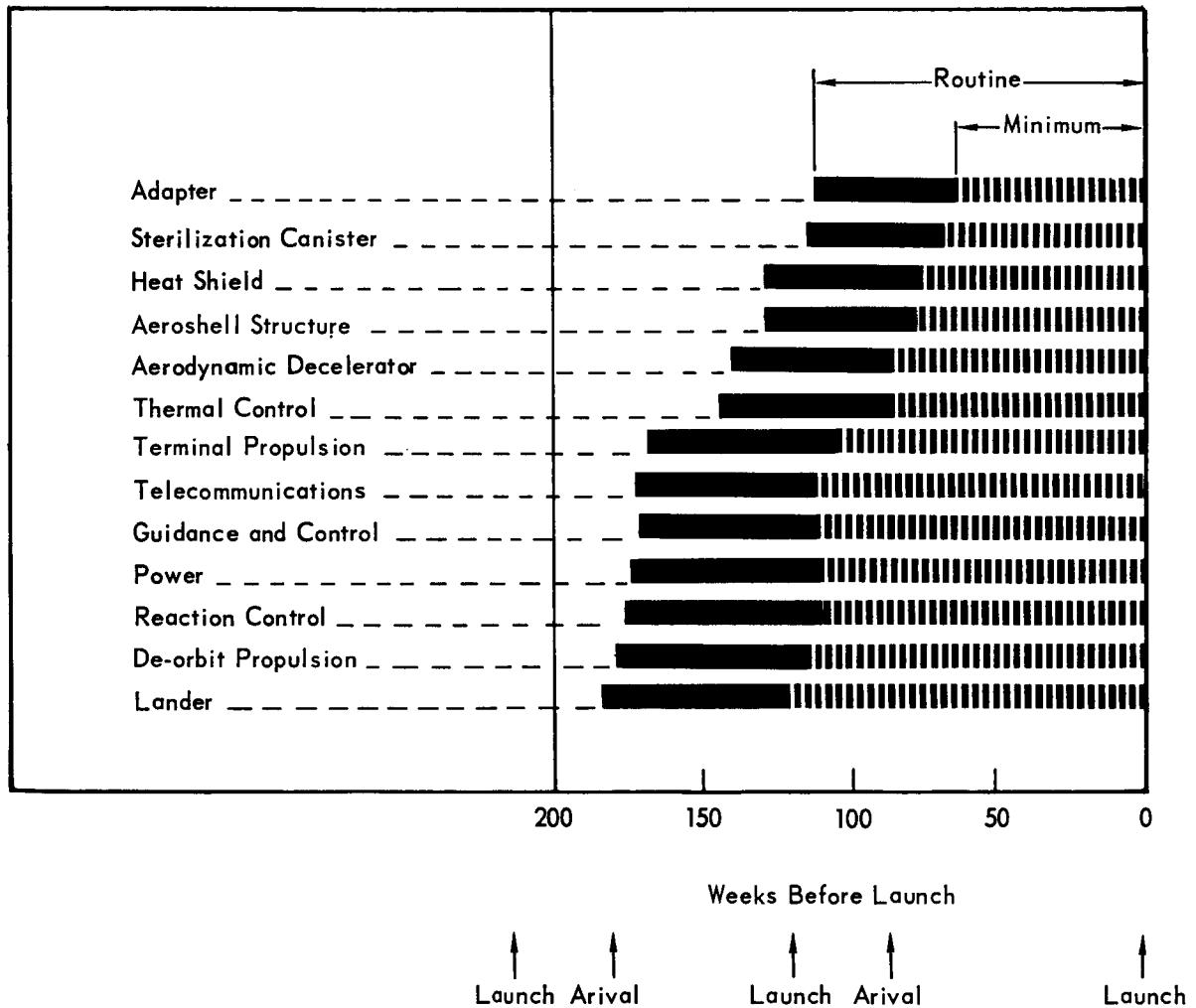
Figure 11-3

11-5

EFFECT OF ATMOSPHERE
DYNAMIC PRESSURE
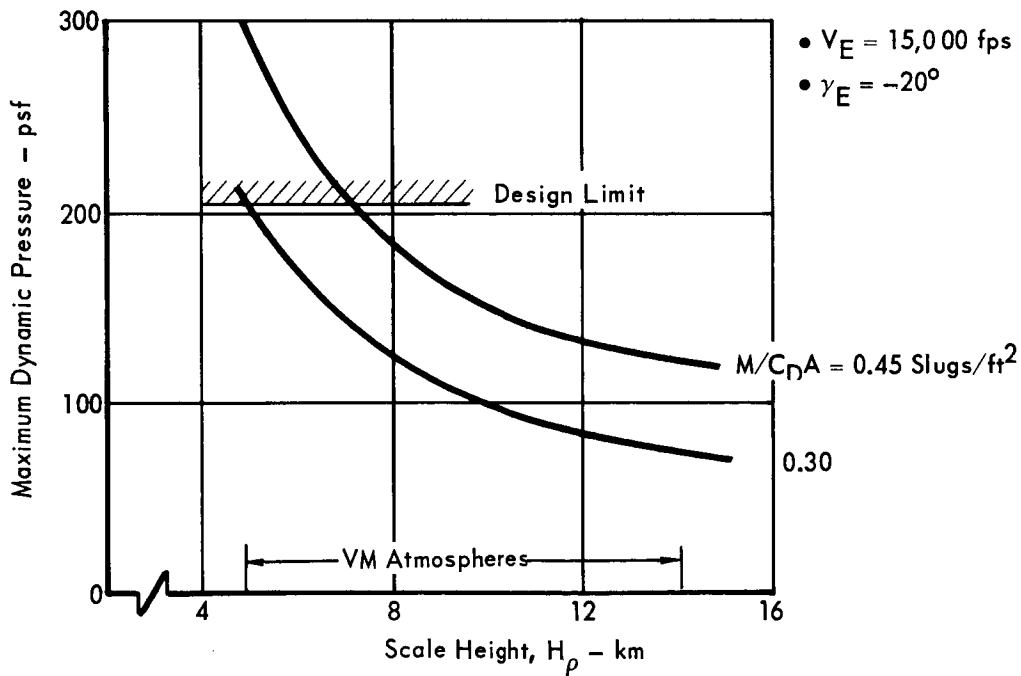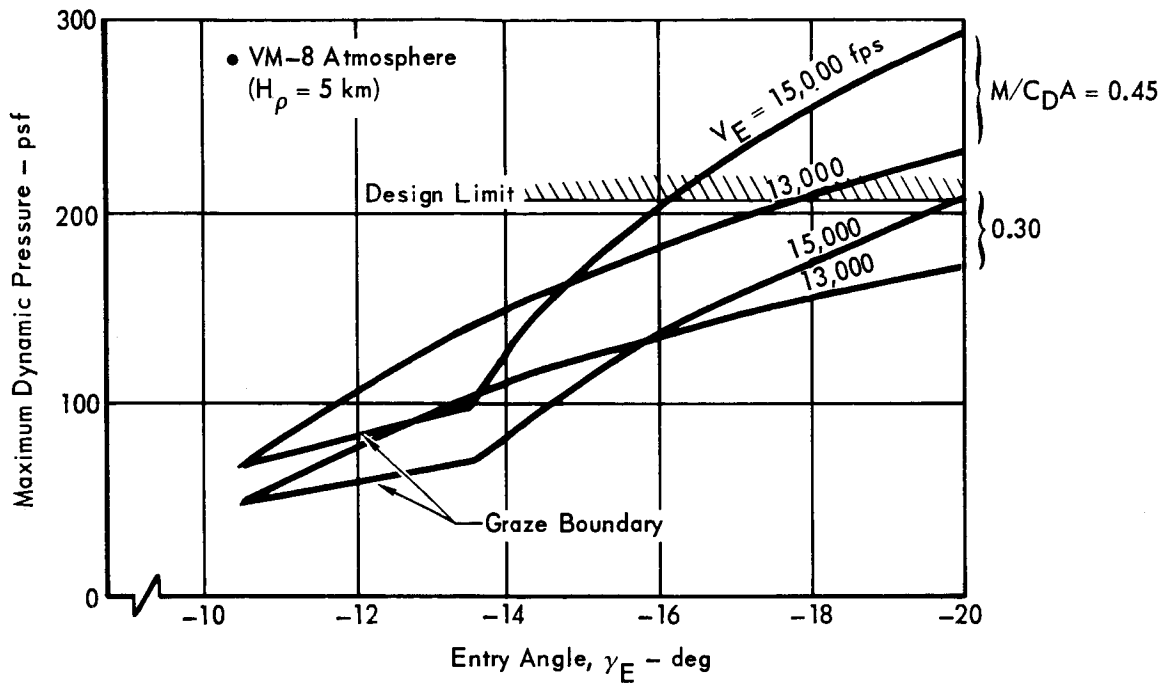
Figure 11-4

11-6

Figure 11-5 shows the capability of the 1973 heat shield design to accommodate the heavier 1975 Capsule. As with the dynamic pressure, the primary atmospheric parameter affecting the total heat load on the ablator is the scale height. In this case, the entry angles must be increased to maintain the capability to survive in the critical VM-3 atmosphere. However, if better atmosphere definition specifies an H_ρ less than 9.3km, the graze entry can be tolerated. The lower entry angle capability can also be achieved by increasing the ablator thickness, a relatively easy change from the 1973 design.

Figure 11-6 shows the shrinking of the V_E-γ_E operational envelope resulting from the increase of M/C_DA from 0.3 to 0.45 slugs/ft^2 while maintaining the full spread of VM atmospheres (scale heights of 5 to 14.3km). The entire 1973 envelope would be available if the scale height uncertainty in 1979 were reduced to a range of 7.2 to 9.3 km.

Another parameter tending to provide operational planning flexibility is the orbit size. To illustrate, the figure shows lines of constant de-orbit velocity increments at a fixed periapse altitude for a range of apoapse altitudes. Entry velocities must be to the right of these lines, so smaller orbits have greater flexibility. The de-orbit angle, δ, also can be manipulated.

The Capsule Bus subsystem standardization status is summarized in Figure 11-7. Consideration of the characteristics of each major subsystem will illustrate the growth capability designed into the 1973 configuration.

11.2.1 <u>Aeroshell and Heat Shield</u> – Drag on the Aeroshell provides over 90% of the deceleration from the entry velocity. The amount of deceleration required depends on entry conditions, the spectrum of the atmospheric definition, and the nature of the decelerators which are to be used subsequently. The Aeroshell has been provided with the maximum possible growth capability by utilizing the largest diameter compatible with the Saturn V launch vehicle.

The Aeroshell structure would be subject to change if the 1979 mission entry conditions and atmosphere definition do not permit operation within the design capability, as discussed earlier. Such a structural change would not be considered a critical redevelopment item.

The ablative heat shield design will not be strongly affected by the changes between the 1973 and 1979 mission requirements. The 1973 heat shield design was based on a worst entry condition, defined by entry at the graze limit with a ballistic parameter value for the 1973 vehicle of 0.3 slugs/ft^2. Although increasing capsule weight does cause more severe heating, an increase in the ablator thickness

EFFECT OF ATMOSPHERE
TOTAL HEAT AT STAGNATION POINT
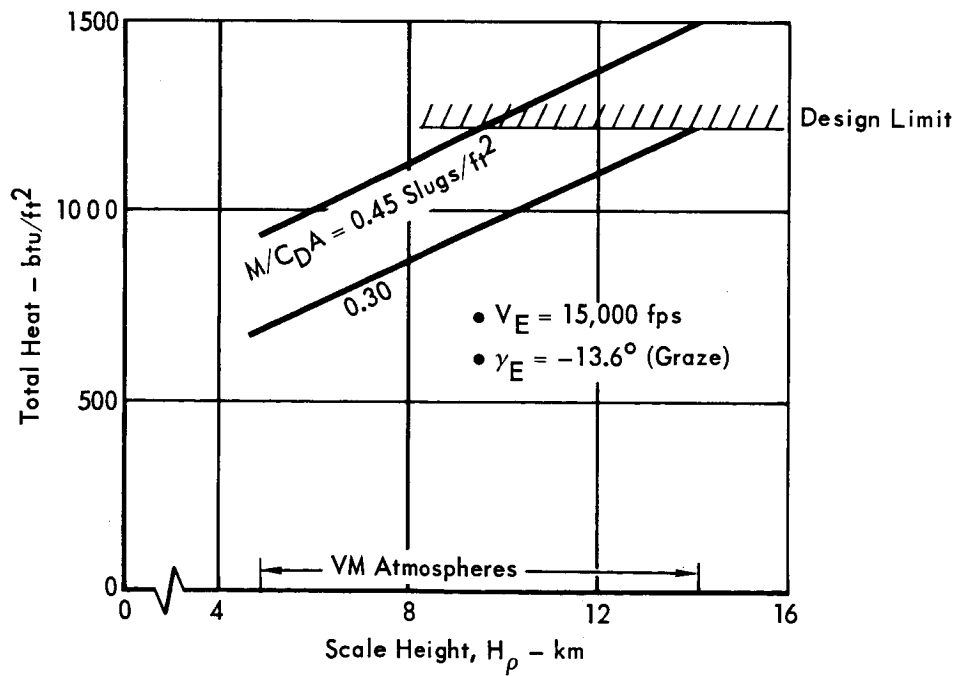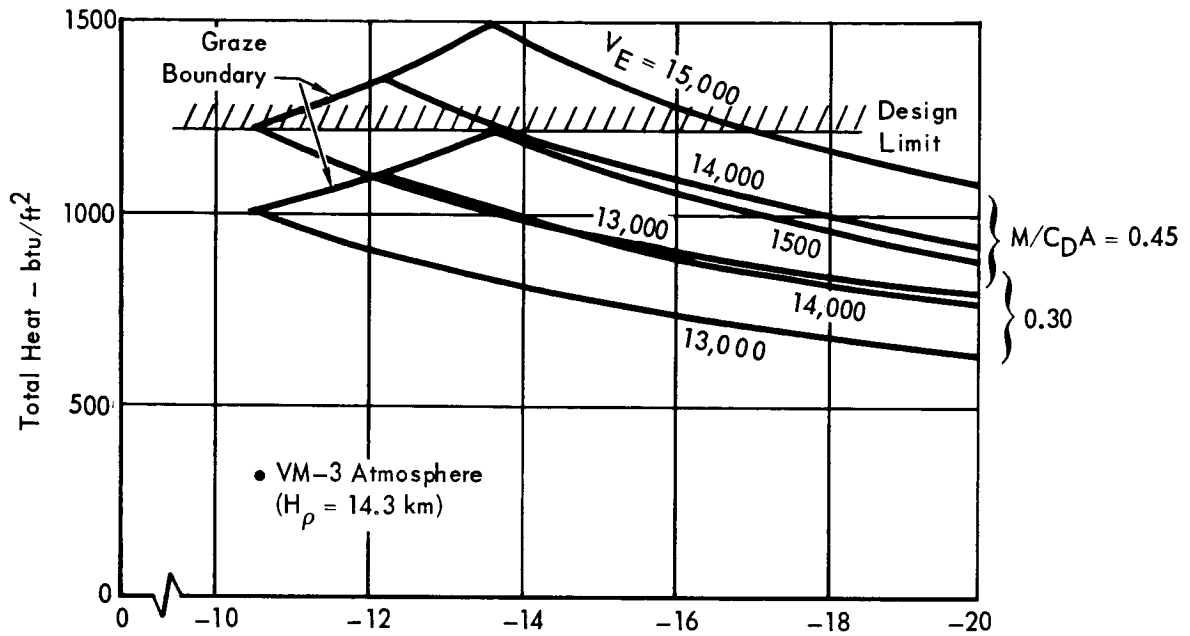
Figure 11-5

OPERATIONAL ENVELOPE FOR 1979 MISSION
$M/C_D A = 0.45$ SLUGS/FT^2

$h_P = 1000$ km

$\Delta V_{DO} = 950$ ft/sec

$\delta = 0°$
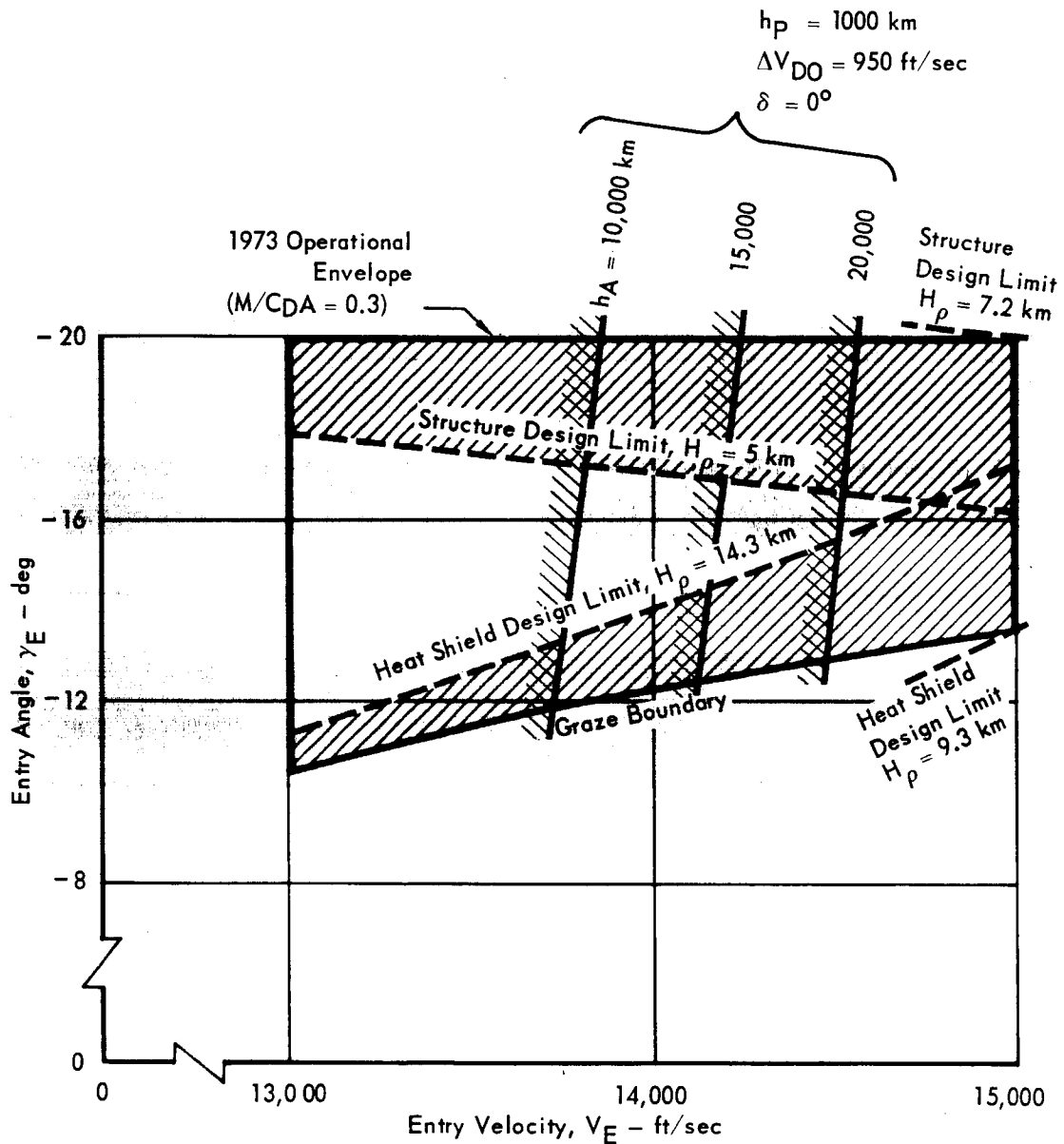
Figure 11-6

CAPSULE BUS STANDARDIZED HARDWARE LIST
FLIGHT CAPSULE WEIGHT 5000 LB IN 1973; GROWTH TO 7000 LB IN 1979

ITEM	STANDARDIZED			DEGREE	COMMENTS
	YES	PARTIAL	NO		
I STRUCTURAL/MECHANICAL				Med	
1. Adapter		√		Med	
a. Structural Assy.		√			The general shape and structural concept are standardized but detail members will be beefed-up for the increased loads.
b. Canister Support		√			
c. Attach Fittings		√			
2. Sterilization Assy.		√		High	
a. Fwd Canister Assy.	√				
b. Aft Canister Assy.		√			Aft canister will have to provide for RTG heat transfer in later missions.
c. Venting Assy.	√				
3. Aeroshell	√	√		Med	
a. Nose Cap Assy.	√				RF transparency capability may influence a later change.
b. Heat Shield Assy.		√			Ablative thickness may be changed to meet mission requirements
c. Structural Assy.					
d. Radome & Window Assy.			√		The window will not be required if the ESP is eliminated from the Flight Capsule.
e. De-Orbit Motor Support			√		The heavier motor and different Surface Laboratory shape will change the struts.
4. Lander		√		Med	
a. Lower Equipment Assy.		√			The configuration will not change but the structure will be beefed-up for increased loads.
b. Upper Equipment Assy.			√		The configuration will be changed to meet different Surface Laboratory weights, shapes, and interfaces.
c. Impact Assy.		√	√		Energy attenuator will be changed to meet mission requirements.
II THERMAL CONTROL				Med	The addition of RTG on later missions has greatest impact on standardization of this system.
1. Heaters		√		Med	Sizes may change to meet equipment requirements.
2. Thermostats	√			100%	Number and location may vary.
3. Insulation			√	Low	Insulation is tailored to the Surface Laboratory configuration and mission requirements.
4. Coatings			√	Low	Application is tailored to the Surface Laboratory configuration and mission requirements.
III AERODECELERATOR				–	The degree of standardization is unknown. If the atmosphere proves to be one of the denser models, then this design will be usable for the 1979 mission. However, if it should be the thinner models, redesign will be required.
1. Aerodecelerator (Parachute)		√			
2. Structure and Mechanisms		√		High	The design concept is standardized but will be beefed-up for the increased loads.
a. Deployment		√			
b. Cover		√			
IV ENTRY SCIENCE PACKAGE					Specialized equipment for the 1973 and possibly 1975 missions.

Figure 11–7

11–10–1

ITEM	STANDARDIZED			DEGREE	COMMENTS
	YES	PARTIAL	NO		
V DE-ORBIT PROPULSION		✓		High	
1. Spherical Solid				High	
a. Rocket Motor	✓				Inert ports standardized; propellant is off-loaded in 1973 by lowering the volumetric efficiency.
b. Nozzle with Ball Release	✓				
c. Igniter Assy.	✓				
VI TERMINAL PROPULSION				High	
1. Propellant Supply	✓			100%	
a. Fuel & Oxidizer Tanks	✓				The tankage is sized for the 1973 mission to prevent excess weight penalty. Later missions (heavier vehicle) will require additional (one each) 1973 mission design tanks.
b. Pyro Valves	✓				
c. Fill Valves	✓				
d. Filters	✓				
e. Check Valves	✓				
f. Burst Diaphram & Relief Valves.	✓				
2. Pressurant Assy.	✓			100%	
a. Tank	✓				Same comment as above.
b. Pyro Valve	✓				
c. Fill Valve	✓				
d. Filter	✓				
e. Regulator	✓				
f. Shut-off Valve	✓				
3. Throttable Engines		✓		High	
a. Throttling Valves	✓				
b. Shut-Off Valves	✓				
c. Access Ports & Plumbing			✓		May be changed to adapt to mission equipment mounting and installation changes.
VII REACTION CONTROL				High	
1. GN_2 Pressurant Assy.	✓			100%	
a. Tank	✓				
b. Regulator	✓				
c. Pyro Valves	✓				
d. Fill Valves	✓				
e. Filters	✓				
f. Check Valves	✓				
g. Shut-Off Valve	✓				
2. Propellant Tank Assy.		✓		High	
a. N_2H_4 Tank	✓				Higher fuel usage for maneuvering but lower usage during cruise because the Capsule Bus inertia in 1979 balances or is better than usage rates for 1973.
b. Fill Valve	✓				
c. Pyro Valve	✓				
d. Filters	✓				
e. Access Port & Plumbing			✓		May be changed to adapt to mission equipment mounting and installation changes.

CAPSULE BUS STANDARDIZED HARDWARE LIST (Continued)
FLIGHT CAPSULE WEIGHT 5000 LB IN 1973; GROWTH TO 7000 LB IN 1979

ITEM	STANDARDIZED				COMMENTS
	YES	PARTIAL	NO	DEGREE	
3. Thrust Chamber Assy.	√			100%	
a. Thrust Chambers	√				
b. Propellant Valves	√				
VIII POWER				100%	
1. Bus Mounted Equipment	√			100%	
a. Battery	√				
b. Battery Charger	√				
c. Power Switching & Logic	√				May be programmed to meet mission requirements.
2. Adapter Mounted Equipment	√			100%	
a. Battery	√				
b. Battery Charger	√				
c. DC to DC Converter	√				
IX GUIDANCE & CONTROL				100%	
1. IMU & Support Electronics	√			100%	
2. Guidance & Control Computer	√			100%	Computer will be programmed to meet mission requirements.
3. Guidance & Control Power Supply	√			100%	
X SEQUENCER				100%	
1. Sequencer & Timmer	√			100%	} Will be programmed to meet mission requirements.
2. Test Programmer	√			100%	
XI RADAR				100%	
1. Landing Radar	√			100%	
a. Antenna Assy.	√				
b. Electronics Assy.	√				

Figure 11–7 (Continued)

11–11 –1

ITEM	STANDARDIZED				COMMENTS
	YES	PARTIAL	NO	DEGREE	
2. Radar Altimeter	✓			100%	
a. Electronics	✓				
b. Altimeter Antenna	✓				
XII TELECOMMUNICATIONS				100%	
1. UHF	✓			100%	Minor items removed on later missions for Entry Science Package elimination.
a. UHF Diplexer	✓				
b. Transmitters	✓				
c. Cruise Commutator	✓				
d. DAS	✓				
e. Parasitic Antenna	✓				
f. Antennas	✓				
2. Instrumentation	✓				
a. Pressure Transducers	✓			100%	
b. Temperature Transducers	✓				
c. Acceleration Transducers	✓				
d. Analog Digital Converter	✓				
3. Spacecraft Mounted Equip.	✓				
a. RF Receivers	✓			100%	
b. Antenna	✓				
c. Data Handling	✓				
c. Data Handling	✓				
XIII PYROTECHNICS				High	
1. Release Mechanisms		✓		High	Some devices may be redesigned for later missions.
2. Initators (EED)	✓			100%	} The EED and circuitry are standardized
3. Circuitry	✓			100%	} for the Flight Capsule.

can be made with no changes in the design of the Aeroshell. Better definition of the Martian environment from the early flights will result in the use of a more representative atmospheric model and a reduction of the design flight envelope to exclude the graze region as a design requirement. This would permit an increased Capsule Bus weight without increasing the ablator thickness.

Inclusion of an RTG power supply will increase the Aeroshell structural and ablative temperatures during all mission phases. For the 1973 operation envelope (Figure 11-5) the increased ablative temperature prior to entry would require a modest amount (5%) of additional ablative weight to maintain a fixed bondline temperature during entry. A less severe operational envelope would require a lesser weight addition.

11.2.2 Canister and Adapter - The major influencing aspect on the Sterilization Canister between the 1973 and later missions is the use of an RTG power supply. The installation of an RTG power supply requires an improvement in capability for heat dissipation to the shroud (or directly to space after demating). The reason is that the RTG must function continuously from Earth throughout the full mission and 95% of the heat it generates is waste heat. No particular restraint is incurred, but differences in surface treatments on the inside and outside are involved, and the multilayer insulation blanket might be removed. Depending on the final design Flight Spacecraft equipment environmental control requirements, an active heat rejection system for the RTG waste heat may become a requirement on the capsule for the in-transit phase of the mission.

The capsule weight increase has a minor effect on the weight of the Capsule Adapter. More important, as the Capsule Lander configuration evolves, the attach point of the adapter to the Capsule Bus is likely to change, requiring a new or modified adapter design. Since the adapter is not a critical subsystem, it probably does not warrant a strong attempt at standardization.

11.2.3 De-orbit Propulsion - The primary growth influence on the de-orbit propulsion system is the increased weight to be de-orbited and the velocity increment required. The velocity increment is dependent on the orbit size and the landing site relative to the orbit orientation, both of which may change as the future mission requirements become more firm. The preferred design includes a motor case large enough to contain the propellant required to provide the same 950 ft/sec velocity increment for the 1979 mission. The propellant grain would be off-loaded for the earlier missions. The total weight penalty imposed by the approach is about 17 lb.

11.2.4 Terminal Propulsion - Landed weight is the principal growth factor in-fluencing the terminal propulsion subsystem design. Our preferred design accommo-dates the expected weight increase by using the minimum thrust level established for the 1973 mission and a throttling ratio sufficiently high to assure adequate deceleration for the 1979 mission.

The propellant tankage is sized for the 1973 mission rather than oversized to accommodate growth. Additional tankage would be provided if necessary for the future missions. It is possible, of course, that improved atmosphere definition will permit operation with the 1973 tankage.

A secondary growth effect is in the configuration of the landed payload. The preferred design has been configured to accommodate a fully mobile laboratory in 1979.

11.2.5 Aerodynamic Decelerator - Because of the numerous parameters affecting parachute performance, it is likely that the 1973 decelerator configuration will not be usable in 1979. If one could expect similar operating Mach numbers, the technology could be directly applicable. If the Martian atmosphere conforms to the more dense VM models, a new decelerator design would not require a full development cycle, but only a minimum of confirming or performance demonstration tests. If the atmosphere turns out to be of lower density, the greater entry weight would require higher deployment Mach numbers, and the parachute-Ballute trade-off would be recon-sidered.

11.2.6 Lander - The uni-disc lander is designed to accommodate the 1979 requirements with minimum redesign. The heavier landing weight can be accommodated by a change in the landing plate and the pallet structure, but the attenuator should be ade-quate. As with other structural changes, in the context of the overall program the lander is considered to be standardized; no major redevelopment effort is required.

11.2.7 Reaction Control - The Aeroshell size, which is fixed, determined the physi-cal dimensions of the reaction control subsystem for de-orbit, descent, and entry. Thrust and impulse sizing to accommodate the most severe requirements expected in all opportunities has been included in the 1973 design.

11.2.8 Guidance and Control Electronics - The electronic guidance and control systems are relatively insensitive to variation in mission parameters. Attitude control for the de-orbit maneuver must, in any event, allow adjustment for particu-lar mission parameters across a range which can be readily predicted. These ad-justments will be made prior to each launch and updated during flight.

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11.2.9 Telecommunications – The CBS telecommunications link requires no growth capability. The requirements are the same for all missions, except that certain minor items could be removed with elimination of the Entry Science Package.

11.2.10 Power – CBS power requirements are sufficiently consistent within the future mission requirements to allow standardization with little or no penalty. While no requirement is foreseen at this time, it would be possible to use the SLS RTG to perform CBS power functions. Some weight would be saved, at the cost of interface complexity.

11.2.11 Thermal Control – Incorporation of an RTG on future missions is the major factor influencing a standardized approach to the thermal control subsystem; the only change expected is removal of the multilayer insulation blanket from the exterior of the Sterilization Canister.

If changing mission profiles would preclude the use of solar heating during orbital descent, the insulation blanket would have to be attached to the heat shield rather than to the canister, and would require a separation sequence prior to entry.

11.2.12 Summary – Considering all of the total and partial standarization shown in Figure 11-7, we find that a substantial portion of the Capsule Bus has been standardized: about 86% by major assembly count, 78% by weight, and 80% by cost.

11-14

APPENDIX A

ENVIRONMENTAL PREDICTIONS

This appendix summarizes the environmental design considerations of the specific environments to which the Capsule Bus System and associated equipment will be subjected. The environmental design predictions detailed herein will be included (as applicable), as an integral portion of the individual subsystem and/or component specifications.

The environmental design predictions described herein were selected to assure survival and satisfactory performance in the desired manner under any reasonable combination of the environmental conditions specified in Figures 1-1 and 1-2.

1.1 GENERAL - The Capsule Bus Sustem environment is defined as the aggregate of the environmental conditions and forces that influence or modify the Capsule Bus System and its performance during its life. The sources of this aggregate are commonly referred to as natural (static-climatic) environment and induced (dynamic-mission) environment. The natural environments are described by measureable parameters for: (1) ambient temperature, (2) ambient pressure, (3) atmospheric density, (4) atmospheric composition, (5) humidity, (6) dew point, (7) precipitation (rain), (8) winds, (9) atmospheric matter, (10) salt sea atmosphere, (11) solar radiation, (12) fungus, (13) electromagnetic radiation, (14) magnetic fields, (15) cosmic radiation, (16) meteoroids, and (17) Mars surface properties. The induced environments are generated by the action of some person or manufactured agent and are described by the measureable parameters: (1) acceleration, (2) shock, (3) vibration, and (4) acoustical noise.

The Capsule Bus System environments are subdivided according to the distinct mission phases of the major component areas of the Capsule Bus System. These major equipment areas are:

    a. Canister exterior surface,

    b. Spacecraft mounted equipment, and

    c. Canister confined equipment.

The following conditions are considered to prevail during the distinct mission phases:

Figure 1-1

NATURAL ENVIRONMENT

(STATIC-CLIMATIC ENVIRONMENTAL REQUIREMENTS)

		CANISTER EXTERIOR SURFACE					SPACECRAFT MOUNTED EQUIPMENT					CANISTER CONFINED EQUIPMENT				
EQUIPMENTS → MISSION PHASE	ENVIRONMENTS	PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE	PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE	PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE

Ambient Temperature
A. 20° to 160°F
B. −60° to 160°F
C. −459° F
D. 120°F to −190°F
E. 40° to 100°F
F. 40° to 160°F
G. Figure 1–3

Ambient Pressure
A. 0 to 11,500 ft. (14.5 to 9.5 psia)
B. Values at 10-second intervals from 0 to 100 seconds (psia) 14.5, 14, 13.2, 11.8, 9.5, 6.6, 4.3, 2.5, 1.4, .7, .4
C. 10^{-14} torr or less
D. Values ranging from B. −0 psid to B. +2.25 psid
E. Figure 1–4 (Reference Figure 1–5)
F. 0 to 50,000 ft. (14.5 to 1.7 psia)
G. 15.5 psia

Atmospheric Density
A. "U.S. Standard Atmosphere, 1962"
B. Approximately 100 particles/cm^3 to upper limit of 1000 particles/cm^3
C. Figure 1–6 (Reference Figure 1–5)

Atmospheric Composition

A. U.S. Standard Atmosphere, 1962

B. Decontamination (gaseous) – 12% ethylene oxide and 88% freon 12 (ETO)

C. Sterilization – Dry heat atmosphere meeting a minimum of 97% nitrogen, a maximum of 2.5% oxygen and a maximum of 0.5% gases other than nitrogen and oxygen.

D. Dry Nitrogen

E. Carbon dioxide as the major constituent with small percentages of oxygen and water vapor. Nitrogen and argon are considered to be the other major components.

F. Deep Space – hydrogen, hydrogen ions, helium, helium ions

Humidity

A. 100% at 20°F to 85°F, and 5% at 105°F

B. Not applicable.

Dew Point

A. Upper limit 85°F, lower limit 40°F

B. Not applicable.

Precipitation (Rain)

A. Period	Amount	Wind Velocity
1 minute	27 in./hr.	to 35 knots
5 minutes	12 in./hr.	to 35 knots
	(to include 1 period of 1 minute conditions)	
10 minutes	9 in./hr.	to 35 knots
	(to include 1 period of 5 minute conditions)	
1 hour	4 in./hr.	to 35 knots
	(to include 1 period of 5 minute conditions and 1 period of 10 minute conditions)	
12 hours	0.66 in./hr.	to 35 knots
	(to include 1 period of 1 hour conditions)	

B. Not applicable

Winds

A. 45 knots for a 5-minute period with gusts to 65 knots with holddown for 55 knots and gusts to 85 knots.

B. Launch winds (material to be added)

C. See Figure 1-7 and 1-8 with Figure 1-5.

D. Not applicable.

NATURAL ENVIRONMENT

(STATIC-CLIMATIC ENVIRONMENTAL REQUIREMENTS) (Continued)

ENVIRONMENTS / EQUIPMENTS — MISSION PHASE	CANISTER EXTERIOR SURFACE — PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE	SPACECRAFT MOUNTED EQUIPMENT — PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE	CANISTER CONFINED EQUIPMENT — PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE
Atmospheric Matter															
A. Sand and Dust — Sand – Particle size 0.01 to 1.00 mm with wind speed above 15 knots	●	●			—	●	●			—					
Dust – Particle size 0.0001 to 0.01 mm with wind speed above 15 knots					—					—					
B. Interplanetary Matter — 100 particles/cm³ to upper limit of 1000 particles/cm³ primarily of hydrogen, hydrogen ions, helium and helium ions.			●		—			●		—			●		
C. Mars Planetary Matter — Particles ranging from 1 to 1000μ in size.				●	—				●	—				●	●
D. Not applicable.					—					—					
Salt Sea Atmosphere															
A. Method 509.1, MIL–STD–810A.	●	●			—	●				—	●	●			
B. Normal salt sea atmosphere (KSC)					—					—					
C. Not applicable.					—					—					
Solar Radiation															
A. 360 BTU/ft2/hr with 105° air temperature.	●	●			—	●	●			—	●	●			
B. "Solar Constant" equals 0.140 watts/cm² (near Earth at 1 AU mean sun distance – AU in astronomical units) to similar value using (1/R² of distance from sun (R in AU)).			●	●	—		●	●	●	—			●	●	●
C. Solar spectrum shaped per "Johnson Curve" varies in integrated intensity from 0.050 to 0.074 watt/cm².			●	●	—				●	—				●	●
D. Not applicable.					—					—	●	●	●		
Fungus															

Figure 1–1 (Continued)

APPENDIX A

A. Method 508.1, MIL–STD–810A.
B. Non-sterile atmosphere.
C. Not applicable.

Electromagnetic Radiation
A. Figure 1–9
B. Interplanetary (material to be added)
C. Mars Atmosphere (material to be added)
D. Mars Surface. (material to be added)

Magnetic Fields
A. On the order of 100 oersteds – Paragraph 1.2.12 (Magnetics) (deperming to 1000 oersteds).
B. Ranges from 0 to 20 gammas with average about 5 gammas – maximum upper limit is 100 gammas.
C. 1/100 Earth magnetic moment.

Cosmic Radiation
Material to be added
Material to be added
Material to be added
Material to be added

Meteoroids
A. Negligible
B. Near Earth – Paragraph 1.2.14 (Meteoroids)
C. Cruise – Paragraph 1.2.14 (Meteoroids)
D. Near Mars – Paragraph 1.2.14 (Meteoroids)

Surface Slope
A. Slopes with inclinations of up to 34 degrees to local horizontal with extent of that 34-degree slope being as much as 100 meters. Slopes longer than 100 meters are expected to be more shallow and a 2-kilometer slope would have a mean angle of no more than 10 degrees.

NATURAL ENVIRONMENT

(STATIC-CLIMATIC ENVIRONMENTAL REQUIREMENTS) (Continued)

ENVIRONMENTS \ MISSION PHASE / EQUIPMENTS	CANISTER CONFINED EQUIPMENT					SPACECRAFT MOUNTED EQUIPMENT					CANISTER EXTERIOR SURFACE				
	PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE	PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE	PRE-LAUNCH	LAUNCH	INTERPLANETARY FLIGHT	MARS ATMOSPHERE	MARS SURFACE
Surface Discontinuities — A. Abrupt changes in slope, within ±34 degrees of horizontal. Ridge and trough formations and conical hills and depressions, formed from material that ranges from loose particles to hard rock.					●										
Surface Roughness — A. Roughness corresponding to sand particles from 10 micron diameter up to rock 5 in. (12.5 cm) in diameter.					●										
Surface Bearing Capacity — A. Bearing capacity of 6 lb./in.^{2} to infinity. Minimum bearing capacity can be assumed to increase at a rate of at least 10 psi/ft for the first few feet of depth.					●										
Surface Thermal Characteristics — A. Maximum temperature +120°F, minimum temperature −190°F, constant temperature of −190°F (possible with cloud cover); average surface albedo for sunlight of 0.05 to 0.35; average surface emissivity of 0.85 to 1.00.					●										
Surface Radar Characteristics — A. Material to be added.					●										

Figure 1-1 (Continued)

INDUCED ENVIRONMENT

(DYNAMIC MISSION ENVIRONMENTAL REQUIREMENTS)

ENVIRONMENTS / EQUIPMENTS	Canister Exterior Surface					Spacecraft Mounted Equipment					Canister Confined Equipment				
MISSION PHASE	Pre-Launch	Launch	Interplanetary Flight	Mars Atmosphere	Mars Surface	Pre-Launch	Launch	Interplanetary Flight	Mars Atmosphere	Mars Surface	Pre-Launch	Launch	Interplanetary Flight	Mars Atmosphere	Mars Surface
Acceleration															
A. Air transportation ± 3.0g vertical, ± 1.5g lateral and ± 3.0g longitudinal (referred to aircraft axes).	●			—	—	●			—	—	●				—
B. Saturn IC – The longitudinal acceleration increases from 1g to 4.75g in 150 seconds and combines with 0.8g in any lateral direction.		●		—	—		●		—	—		●			—
Saturn II – The longitudinal acceleration increases from 1.0g to 2.9g in 380 seconds and combines with 0.8g in any lateral direction.															
Saturn IVB – The longitudinal acceleration increases from 0.5g to 4.2g in 450 seconds and combines with 0.3g in any lateral direction.															
C. Acceleration of ± 2g longitudinally and ± 1g laterally.			●	—	—			●	—	—			●		—
D. De-orbit motor acceleration will be 1.6g longitudinally.				—	—				●	—				●	—
E. Entry acceleration will be 2.5g laterally and 22.5g longitudinally.				—	—				—	—				●	—

SHOCK

A. Handling, transportation and storage – Design to withstand requirements of MIL–STD–810A, Method 516.1, Procedures I, III and VI.

B. Staging – To be defined.

C. Pyrotechnic – To be defined.

D. Landing

Initial Design – Half sine wave pulse shape with peak value of 100g and nominal duration of 10 millisecond.

Final Design – To be defined.

Vibration

A. Pre-Launch – Design to withstand requirements of MIL–STD–810A, Method 514.1, Figure 6, Curve A and B.

B. Launch – Complex wave omnidirectional.

Random – Power Spectral Density (PSD) of $0.1g^2$/cps between the frequencies of 100 and 1500 cps with 6 db rolloff in the spectrum above and below these frequencies in the over-all frequency band of 20 to 2000 cps.

Sweeping Sine Wave – 0.8 inch double amplitude displacement between the frequencies of 2 to 10 cps; 4.0g rms between the frequencies of 10 to 300 cps.

C. Entry

Random – Power Spectral Density (PSD) of $0.005g^2$/cps between the frequencies of 100 and 1500 cps with 6db rolloff in the spectrum above and below these frequencies in the over-all frequency band of 20 to 2000 cps.

Acoustical Noise

A. 145 db Over-all – Sound pressure level spectrum to be determined when shroud configuration is known.

B. Negligible

C. Not applicable.

Figure 1–2

a. <u>Pre-Launch Phase</u> - Capsule Bus System (Mission) - Includes terminal
   sterilization with pressure sealing within the Sterilization Canister
   and conditions prior to launch. This phase includes air transportation
   from McDonnell Douglas Corporation to the launch site and the pre-launch
   operations.

   Capsule Bus System (Equipments) - Includes handling, transportation
   and storage on equipment entity basis in addition to mission pre-launch
   environments above.

b. <u>Launch</u> - Launch Operations Environments - The Canister confined equipment
   is pressure sealed within the Sterilization Canister throughout this phase.

c. <u>Interplanetary Flight</u> - The Canister confined equipment is pressure
   sealed within the Sterilization Canister throughout this phase.

d. <u>Mars Atmosphere and Surface</u> - The Canister confined equipment is pressure
   sealed within the Sterilization Canister throughout this phase.

1.2 ENVIRONMENTAL DESIGN PARAMETERS - The parameter values presented in this
report were selected from the specified references on the basis of their appli-
cability in view of the Capsule Bus System requirements, and mission concept.
Each value is intended to be considered as the mission conditions which the
Capsule Bus System may encounter and as such are feasible least upper bounds or
feasible greatest lower bounds. Therefore, the Capsule Bus System and associated
equipment must be designed to survive and satisfactorily perform in the desired
manner under any reasonable combination of the mission conditions noted in
Figures 1-1 and 1-2. Test margins or safety factors are not included. The
following environmental conditions are further defined in order to clarify the
notations of Figures 1-1 and 1-2.

1.2.1 <u>Ambient Temperature</u> - Solutions of temperatures applicable to the canister
confined equipment level requires the use of the figure on the following page.
Figure 1-3 presents the expected temperature for the VOYAGER Flight Capsule
regions throughout the battery powered 1973 mission. The ranges in the values
during the cruise phase arise from variations in Capsule Lander insulation
performance and the temperature at which critical equipment is maintained. The
orbital descent and Mars entry temperatures vary with the Flight Capsule orien-
tation with respect to the Sun and entry trajectory flown. The post-landing

VOYAGER MISSION TEMPERATURES BATTERY POWERED FLIGHT CAPSULE

AREA		PRE-LAUNCH (DEG)	LAUNCH (DEG)	CRUISE AND MARS ORBIT (DEG)	ORBITAL DESCENT (DEG) Ⓐ	ENTRY AT 800,000 FT. (DEG) Ⓒ	POST LANDING (DEG)
1		20 to 160	40 to 160	40 to 100	N/A	N/A	N/A
2		20 to 160	-60 to 160	-120 to -35	N/A	N/A	N/A
3	A	20 to 160	-60 to 160	-120 to -40	N/A	N/A	N/A
	B	20 to 160	-60 to 160	-330 to -310	N/A	N/A	N/A
Thermal Curtain 4	A	20 to 160	-60 to 160	-140 to -50	-150 to 30	-150 to 800	N/A
	B	20 to 160	-60 to 160	-330 to -310	N/A	N/A	N/A
	C	20 to 160	-60 to 160	-120 to -40	-290 to -210	-290 to 1000	N/A
Inside SL & ESP Within Aeroshell 5		20 to 160	40 to 160	40 to 125	40 to 125	40 to 125	50 to 125
6	A	20 to 160	-60 to 160	-150 to -60	-100 to 80	1700 to 2100	N/A
	B	20 to 160	-60 to 160	-330 to -310	N/A	N/A	N/A
Inside SL & ESP After Separation		N/A	N/A	N/A	N/A	N/A	50 to 125
SL & ESP External Surface		20 to 160	-60 to 160	-120 to -35 Ⓑ	-210 to 180 Ⓑ	-150 to 800 Ⓓ	-190 to 120
Mars Surface		N/A	N/A	N/A	N/A	N/A	-190 to 120
Mars Atmosphere		N/A	N/A	N/A	N/A	N/A	-190 to 120

All Temperatures in °F

Ⓐ Assumes Solar Orientation: The angle between the Capsule Bus roll axis (centerline) and the solar rays is maintained between 0° and 50°.

Ⓑ Exposed Surface Temperatures; Temperature sensitive equipment will require insulation and/or heaters.

Ⓒ With insulation and canister removed from Aeroshell.

Ⓓ Insulated temperature sensitive equipment with insulation and/or heaters will vary from region ranges as shown.

Figure 1-3

VOYAGER FLIGHT CAPSULE REGIONS

Multilayer Insulation

3B

3A

Aeroshell Edge

2

4C

4A

4B

Ablator

Aeroshell Structure

Multilayer Insulation

6B

6A

ESP

SLS

5

1

2

3A

3B

4C

4A

4B

Thermal Curtain

Sterilization Canister
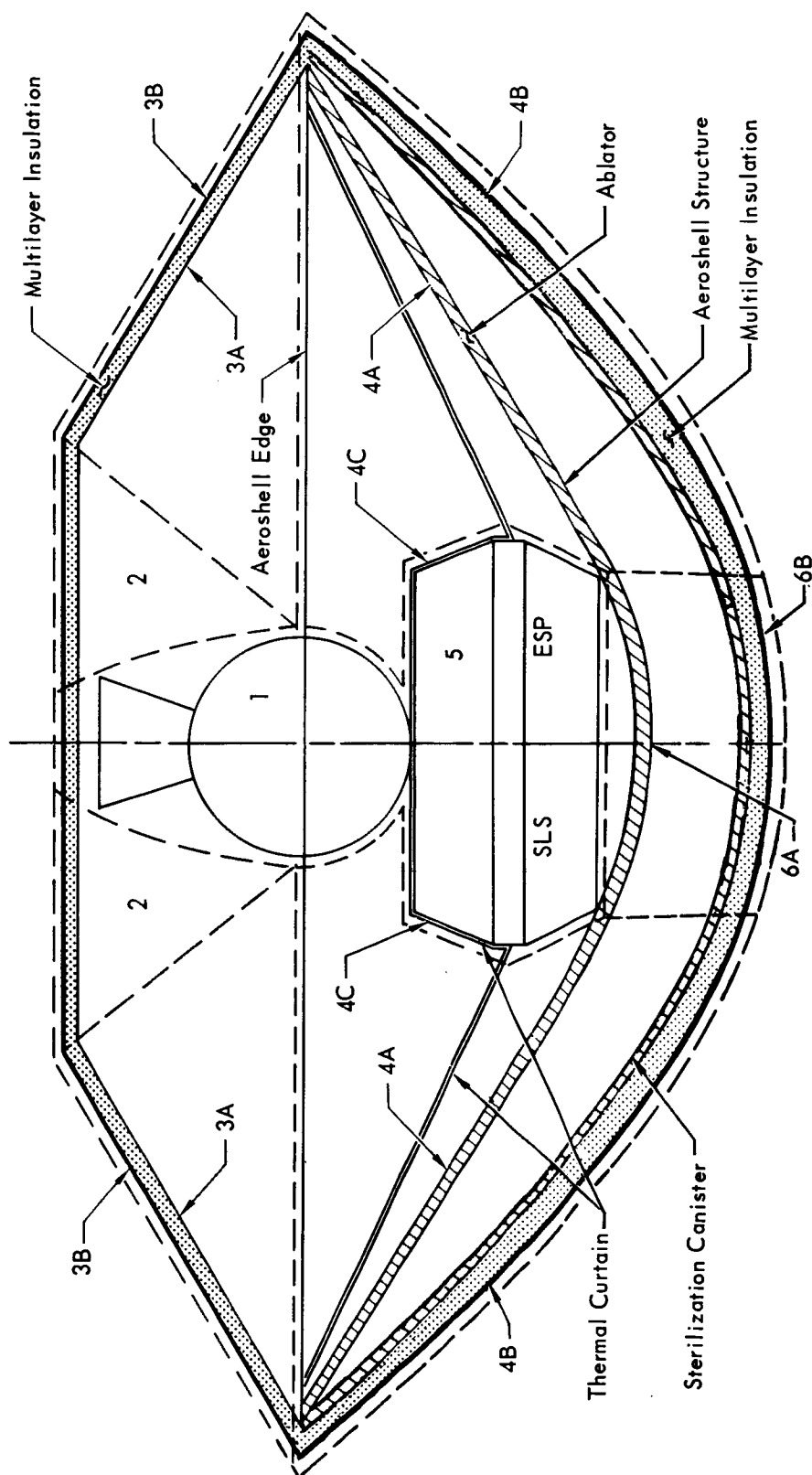
ranges account for night and day periods. Spacecraft mounted equipment was assumed to be exposed and protected to the same temperature range as the lander area within the Aeroshell of the Flight Capsule.

1.2.2 Ambient Pressure - The Canister confined equipment will be maintained at not less than ambient + 0.5 psi to + 2.25 psi by the Sterilization Canister up to launch. The entry, landing and post-landing design pressure region is defined per Figure 1-4 (Reference Figure 1-5 for Atmospheric Model Data).

1.2.3 Atmospheric Density

    a. Near Earth - The Earth atmosphere described by the "U.S. Standard Atmosphere, 1962," shall be used. At high altitudes, variations in the observed density from the model atmosphere which are as large as a factor of 5 may occur because of variation of solar activity and because of diurnal and seasonal variations. Similar variations in the pressure may result.

    b. Cruise - The molecular density of interplanetary matter is approximately 100 particles/cm^3 with an upper limit of 1000 particles/cm^3. This matter is composed primarily of hydrogen, hydrogen ions, helium and helium ions. The density varies with solar activity and, in addition, probably decreases with increasing distance from the Sun.

    c. Near Mars - The design region for Mars atmospheric density is shown in Figure 1-6. The Mars atmospheric data is tabulated in Figure 1-5.

1.2.4 Humidity - Condition does not exist internally for the Canister confined equipment after Sterilization Canister sealing under the positive pressure dry nitrogen atmosphere.

1.2.5 Dew Point - Condition does not exist internally for the Canister confined equipment due to Sterilization Canister sealing under the positive pressure dry nitrogen atmosphere.

1.2.6 Precipitation (Rain) - Condition does not exist internally for the Canister confined equipment due to Sterilization Canister sealing under positive pressure dry nitrogen atmosphere.

1.2.7 Mars Design Winds - Mars atmospheres VM-7 and VM-8 represent the worst case design winds and are illustrated in Figures 1-7 and 1-8.

1.2.8 Salt Sea Atmosphere - Condition does not exist internally for the Canister confined equipment due to Sterilization Canister Sealing under the positive pressure dry nitrogen atmosphere.

ATMOSPHERIC PRESSURE
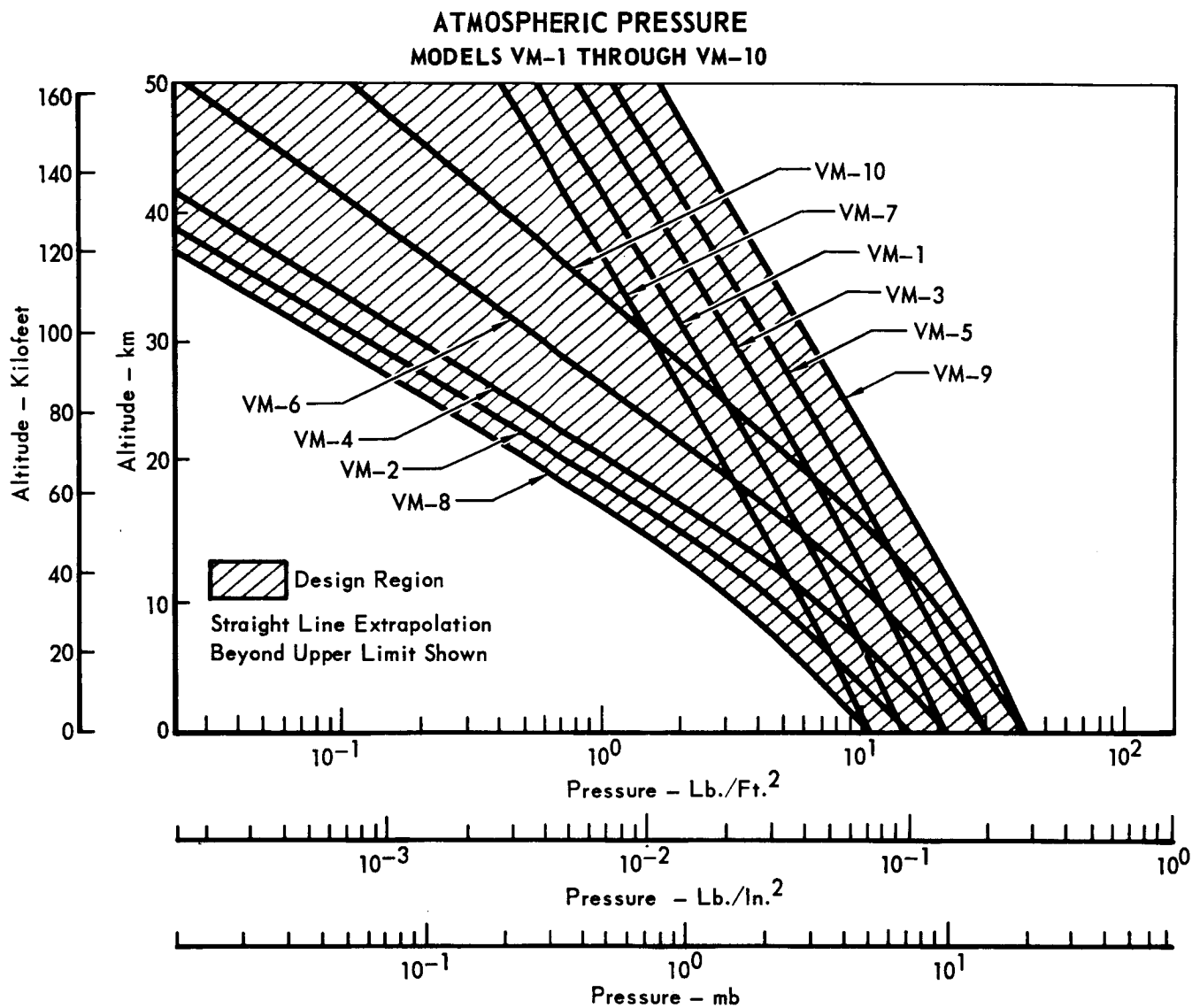## MODELS VM-1 THROUGH VM-10

Design Region

Straight Line Extrapolation
Beyond Upper Limit Shown

VM-10
VM-7
VM-1
VM-3
VM-5
VM-9
VM-6
VM-4
VM-2
VM-8

Altitude – Kilofeet

Altitude – km

Pressure – Lb./Ft.^{2}

Pressure – Lb./In.^{2}

Pressure – mb

MARS ATMOSPHERIC MODEL DATA

PROPERTY	SYMBOL	DIMENSION	VM-1	VM-2	VM-3	VM-4	VM-5	VM-6	VM-7	VM-8	VM-9	VM-10
Surface Pressure	P_o	mb	7.0	7.0	10.0	10.0	14.0	14.0	5.0	5.0	20.0	20.0
		lb/ft²	14.6	14.6	20.9	20.0	29.2	29.2	10.4	10.4	41.7	41.7
Surface Density	D_o	$(gm/cm^3)10^5$	0.955	1.85	1.365	2.57	1.91	3.08	0.68	1.32	2.73	3.83
		$(slugs\ ft^3)10^5$	1.85	3.59	2.65	4.98	3.7	5.97	1.32	2.56	5.30	7.44
Surface Temperature	T_o	°K	275	200	275	200	275	200	275	200	275	200
		°R	495	360	495	360	495	360	495	360	495	360
Stratospheric Temperature	T_s	°K	200	100	200	100	200	100	200	100	200	100
		°R	360	180	360	180	360	180	360	180	360	180
Acceleration of Gravity at Surface	g	cm/Sec²	375	375	375	375	375	375	375	375	375	375
		ft/sec²	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3	12.3
Composition (Percent)												
CO₂ (by Mass)			28.2	100.0	28.2	70.0	28.2	35.7	28.2	100.0	28.2	13.0
CO₂ (by Volume)			20.0	100.0	20.0	68.0	20.0	29.4	20.0	100.0	20.0	9.5
N₂ (by Mass)			71.8	0.0	71.8	0.0	71.8	28.6	71.8	0.0	71.8	62.0
N₂ (by Volume)			80.0	0.0	80.0	0.0	80.0	32.2	80.0	0.0	80.0	70.5
A (by Mass)			0.0	0.0	0.0	30.0	0.0	35.7	0.0	0.0	0.0	25.0
A (by Volume)			0.0	0.0	0.0	32.0	0.0	38.4	0.0	0.0	0.0	20.0
Molecular Weight	M	mol^{-1}	31.2	44.0	31.2	42.7	31.2	36.6	31.2	44.0	31.2	31.9
Specific Heat of Mixture	C_P	cal/gm °C	0.230	0.166	0.230	0.1530	0.23	0.174	0.230	0.166	0.230	0.207
Specific Heat Ratio	σ		1.38	1.37	1.38	1.43	1.38	1.45	1.38	1.37	1.38	1.41
Adiabatic Lapse Rate	Γ	°K/km	-3.88	-5.39	-3.88	-5.85	-3.88	-5.14	-3.88	-5.39	-3.88	-4.33
		°R/1000 ft	-2.13	-2.96	-2.13	-3.21	-2.13	-2.82	-2.13	-2.96	-2.13	-2.38
Tropopause Altitude	h_T	km	19.3	18.6	19.3	17.1	19.3	19.4	19.3	18.6	19.3	23.1
		kilofeet	63.3	61.0	63.3	56.1	63.3	63.6	63.3	61.0	63.3	75.8
Inverse Scale Height (Stratosphere)	β	km^{-1}	0.0705	0.199	0.070	0.193	0.0705	0.1655	0.0705	0.199	0.0705	0.145
		$ft^{-1} \times 10^5$	2.15	6.07	2.15	5.89	2.15	5.05	2.15	6.07	2.15	4.41
Free Stream Continuous Surface Wind Speed	$\bar{v}$	ft/sec	186.0	186.0	156.0	156.0	132.0	132.0	220.0	220.0	110.0	110.0
Maximum Surface Wind Speed	v_{max}	ft/sec	380.0	380.0	310.0	310.0	270.0	270.0	450.0	450.0	225.0	225.0
Design Gust Speed	v_g	ft/sec	200	200	150.0	150.0	150.0	150.0	200.0	200.0	100.0	100.0
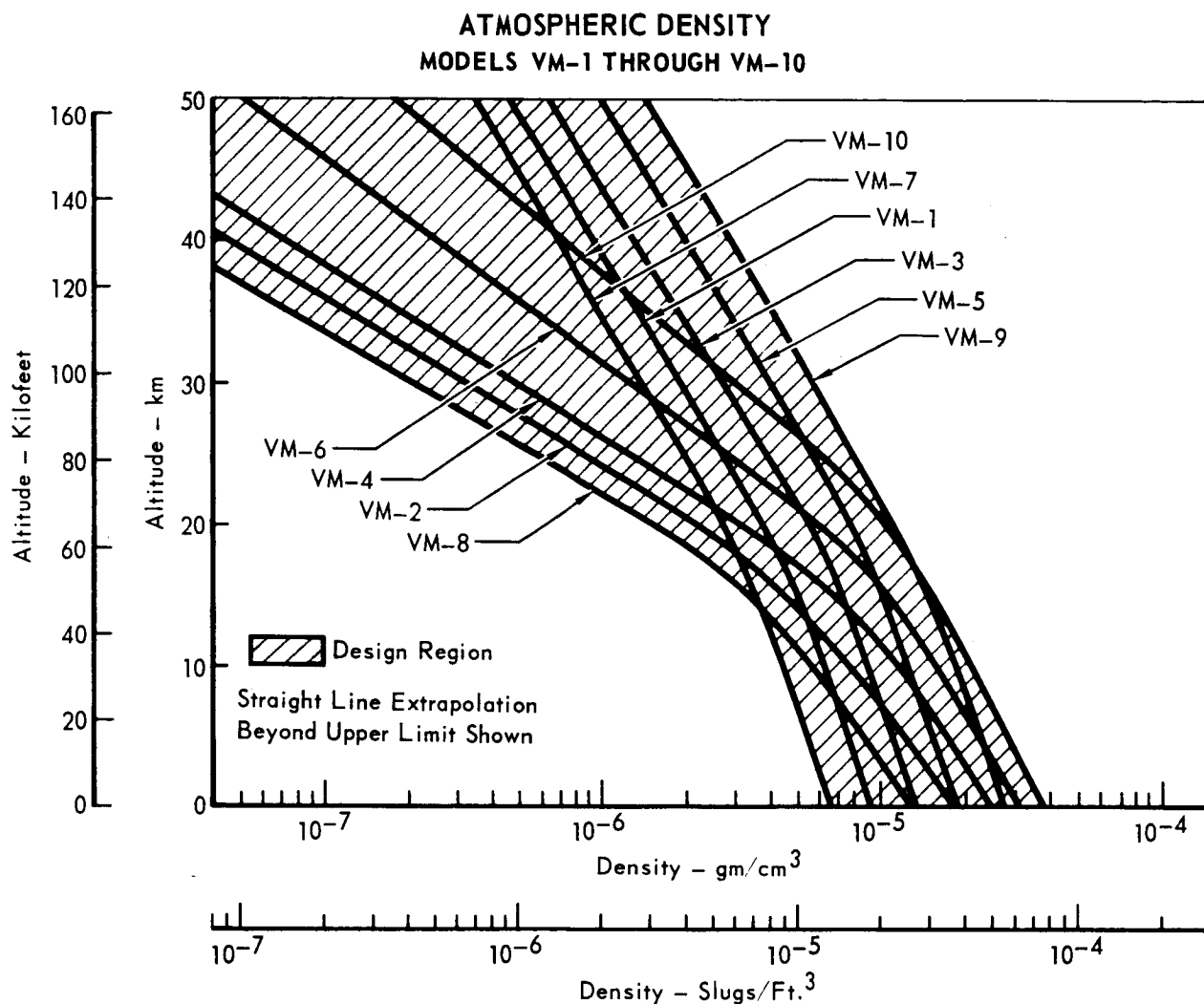
ATMOSPHERIC DENSITY
MODELS VM-1 THROUGH VM-10

Figure 1-6

ENTRY WIND PROFILE
VM-7 AND VM-8 ATMOSPHERE

Note:
1. Wind profile and spikes constant from 50,000 to 90,000 Ft.
2. Profile starts at an altitude of 324 Ft.
3. A gust velocity of 200 fps can be applied instantaneously up to an altitude of 90,000 Ft. However, gust velocites and/or wind shear velocities are to be considered separately.
4. It is projected that one wind shear cycle will be experienced during the descent period. This wind shear cycle may be either negative and then positive or positive and then negative as shown.

Maximum Mean Free Stream Wind

Maximum Wind Envelope

Wind Shear Cycle

Altitude — Kilofeet

Wind Velocity — Ft/Sec

SURFACE BOUNDARY LAYER PROFILE
VM-7 AND VM-8 ATMOSPHERE

Note:
1. Wind directions may be normal to local vertical or parallel to local terrain blowing upslope, downslope or cross slope.
2. The maximum surface wind speed (450 Ft/Sec) is the maximum wind speed at 3.24 Ft. that a long life (greater than 30 days) landed stage must accomodate.
3. For elevations above 1000 Ft., the wind direction is considered normal to local vertical.

Surface Boundary Layer Profile 1973 Mission

Free Stream Continuous Surface Wind Speed 220 Ft/Sec

Altitude — Ft.

Wind Velocity — Ft/Sec

1.2.9 <u>Solar Radiation</u> - Condition not applicable internally for the Canister confined equipment due to containment within the Sterilization Canister.

1.2.10 <u>Fungus</u> - Condition not applicable internally for the Canister confined equipment due to decontamination and sterilization processes.

1.2.11 <u>Electromagnetic Radiation</u> - The radio frequency (RF) power density levels for spacecraft test areas may be high enough to provide interference to a spacecraft or its checkout. The RF environment is dependent on the facility to be used. A facility with a good unipotential ground plane in the test areas, with suppression of interference-producing equipment, and with shielded and filtered equipment enclosures will have less ambient RF levels than one without these safeguards.

An electromagnetic environment created by Cape Kennedy RF systems, such as radars, will be present at some intensity within the Explosive Safe Area (ESA). Information is needed on the shielding properties of the buildings to be used in the frequency ranges of interest.

At the launch pad, the Launch Vehicle RF transmitters and the Cape Kennedy RF sources, such as radars, will provide an electromagnetic environment to the Capsule Bus System. No information exists on the shielding property of the vehicle shroud, but a transparent shroud is assumed to be the worst case. The RF power densities listed in Figure 1-9 shall be used.

In addition to the frequency ranges listed in Figure 1-9, very low frequency radiation spectra of lightning discharges occur from approximately 1 to 40 kHz.

Power Density Levels

Frequency (mHz)	ESA	Power Density DBM/(meter)^2			Earth Orbit
		Enroute	Pad	Ascent	
0.150 - 100	2	2	2	2	-
100 - 150	4	4	4	4	-
225 - 260	-	-	36	36	36
400 - 550	10	10	10	10	-
1,200 - 1,400	20	30	30	30	-
2,200 - 2,900	-	0	-	-	-
5,400 - 5,900	18	28	28	28	23
8,500 - 10,000	20	30	30	30	23

Figure 1-9

1.2.12 Magnetics

    a. Magnetic Fields - In the manufacture and shipment of the Capsule Bus System and the many assemblies and components thereof, exposure to magnetic fields more intense than the Earth's field and in addition to the Earth's field can be expected. Subassemblies, assemblies, and assembled Capsule Bus System will be subjected to dc magnetic fields on the order of 100 oersteds. This represents the maximum external environment to be encountered and shall be used as a basis for design.

        Vibration exciters used in environmental testing have stray magnetic fields on the order of 35 oersteds in the area of item to be shaken.

        Tools made of magnetic materials have magnetic fields associated with them. These fields vary considerably but can reach values on the order of 100 oersteds close to the tool if it has not been depermed (demagnetized).

    b. Deperming (Demagnetizing) - Subassemblies, assemblies and the assembled Capsule Bus System may be exposed to concentrated 60 cps deperming (demagnetizing) fields on the order of 100 oersteds with system level tests restricted to 1 cps. Small components and non-electric hardware may be exposed to concentrated 60 cps deperming (demagnetizing) fields on the order of 1,000 oersteds.

1.2.13 Cosmic Radiation - Material to be added during subsequent study.

1.2.14 Meteoroids - The meteoroid environment presented herein shall be used to evaluate the meteoroid hazard for the Capsule Bus System Sterilization Canister and exposed equipments. The environments are defined for the near-Earth, cruise, and near-Mars mission phases and include the sporadic and stream meteoroids, the Earth and Mars dust belts, and the asteroidal debris. The specific environments associated with each mission phase are defined in Figure 1-10, and are based on the data presented in JPL Document SE 003 BB 001-1 B28, "Draft VOYAGER Environmental Predictions Document."

    a. Near-Earth Phase - The near-Earth phase begins with injection into Earth orbit and ends with injection into the cruise phase trajectory. The environment for this phase consists of the Earth-dust-belt particles (N_1, Figure 1-10). The spacecraft will be exposed to this environment for .10 days.

METEOROID ENVIRONMENT

MISSION PHASE	METEOROID FLUX		VELOCITY (V_P)	DENSITY (ρP)
	LOGARITHMIC NOTATION: IMPACTS/M²–SEC	EXPONENTIAL NOTATION: IMPACTS/FT²–DAY		
Near Earth (τ = .10 Day)	$\text{Log } N_1 = -17.0 - 1.70 \text{ Log } m$	$N_1 = 8.02 \times 10^{-14} m^{-1.70}$	5	.40
Cruise Cometary Debris (τ = 220 Days)	Meteoroids of mass < 10^{-2} gm: $\text{Log } N_{2,1} = -14.48 - 1.34 \text{ Log } m + \text{Log } F$	$N_{2,1} = F[2.66 \times 10^{-11} m^{-1.34}]$	40	.40
	Meteoroids of mass $\geq 10^{-2}$ gm: $\text{Log } N_{2,2} = -13.80 - \text{Log } m + \text{Log } F$	$N_{2,2} = F[1.277 \times 10^{-11} m^{-1.0}]$	40	.40
Asteroidal Debris (τ = 220 Days)	Stone Meteoroids: $\text{Log } N_3 = -16.2 - .77 \text{ Log } m + 3.4(A-1)$	$N_3 = 2.01 \times 10^{-16} (m^{-.77})(10^{3.4 \overline{A}})$	40	3.5
	Iron Meteoroids: $\text{Log } N_4 = -16.9 - .76 \text{ Log } m + 3.4(A-1)$	$N_4 = 4.02 \times 10^{-16} (m^{-.76})(10^{3.4 \overline{A}})$	40	7.7
Near Mars Distances One Mars Radius (τ = 27 Days)	Meteoroids of Mass < 10^{-2} gm: $\text{Log } N_{5,1} = -14.08 - 1.34 \text{ Log } m$	$N_{5,1} = 6.63 \times 10^{-11} m^{-1.34}$	40	.40
	Meteoroids of Mass $\geq 10^{-2}$ gm: $\text{Log } N_{5,2} = -13.40 - \text{Log } m$	$N_{5,2} = 3.20 \times 10^{-10} m^{-1.0}$	40	.40
Distances One Mars Radius (τ = 3 Days)	$\text{Log } N_6 \ll -17.60 - 1.70 \text{ Log } m$	$N_6 < 2.02 \times 10^{-14} m^{-1.70}$	2.5	.40

Notes:
1) N = Number of Impacts of Mass m and Greater
2) m = Meteoroid Mass, gm
3) $\overline{F}$ = Stream Meteoroid Factor (Ref. Figure 1–11)
4) $\overline{A}$ = Average Distance from Sun During Time Interval τ, A.U.
5) τ = Duration of Mission Phase, Days
6) ρP = Meteoroid Density, gm/cm³
7) V_P = Meteoroid Velocity, km/Sec.

Figure 1–10

b. Cruise Phase - The cruise phase begins with injection into the cruise phase trajectory and ends with insertion into Mars orbit. The environment for this phase consists of the sporadic and stream meteoroids for cometary debris (N_2, Figure 1-10), and the stone and iron meteoroids of astroid debris (N_3 and N_4, Figure 1-10).

Stream meteoroid effects are included in the flux expression for cometary debris by use of the meteoroid stream factor, F. This factor is the ratio of the average rate of stream meteoroids during the time interval to the average rate of sporadic meteoroids. The meteoroid stream factors are given in Figure 1-11.

For cometary debris, an increase in the flux occurs when the mass is less than 10^{-2} gm. Therefore, if the minimum mass that will penetrate the canister is less than 10^{-2} gm, the meteoroid flux equation $N_{2,1}$ shall be used. Similarly, if the mass is greater than 10^{-2} gm, the meteoroid flux equation $N_{2,2}$ is used.

The astroidal debris consists of both stone and iron meteoroids and the flux varies in space. Therefore, the hazard to the Capsule Bus System Sterilization Canister and exposed equipments varies during the cruise phase depending on distance from the Sun. The average distance from the Sun during the time interval τ $(\bar{A})$ shall be used in the meteoroid flux equations N_3 and N_4 to account for this variation flux. This factor $(\bar{A})$ is shown in Figure 1-13 and is based on the typical cruise phase trajectory shown also.

The Capsule Bus System Sterilization Canister and exposed equipments shall be exposed to the cruise phase environment for 220 days.

c. Near-Mars Phase - The near-Mars phase begins with injection into Mars orbit and ends with entry into the Mars atmosphere. The Flight Capsule shall be in orbit about Mars for a maximum of 30 days. The environment for this phase consists of the sporadic meteoroids (N_5, Figure 1-10), when the distance from the Flight Capsule to the surface of Mars is greater than one Mars radius; and the Mars dust belt (N_6, Figure 1-10), when the distance from the Flight Capsule to the surface of Mars is less than one Mars radius. The Capsule Bus System Sterilization Canister and exposed equipment shall be exposed to the sporadic meteoroids for 27 days, and to the dust belt for 3 days.

METEOROID STREAM FACTOR, F

DISTANCE FROM SUN (A.U.)	F	τ (DAYS)
1.0 to 1.25	1.0	84
1.25 to 1.36	3.0	29
1.36 to 1.43	5.0	20
1.43 to 1.49	3.0	19
1.49 to 1.56	2.5	25
1.56 to 1.66	1.0	43

Figure 1-11

SHIELDING FACTOR, S_F

MISSION PHASE	S_F
Near Earth	.50
Cruise	1.00
Near Mars	
*Distance > One Mars Radius	.98
*Distance < One Mars Radius	.90

*Distances from surface of Mars to flight capsule.

Figure 1-12

APPENDIX A

EARTH MARS TRAJECTORY
CRUISE PHASE

$$A \approx 1.31 + .42 \sin\left[\frac{(\tau - 100)\pi}{380}\right]$$

$$\bar{A} = 1.31 + \frac{34.4}{\tau} - \frac{50.8}{\tau} \cos\left[\frac{(\tau - 100)\pi}{380}\right]$$

Spacecraft Distance to Sun, A – A.U.

Time from Cruise Phase Injection, τ – days
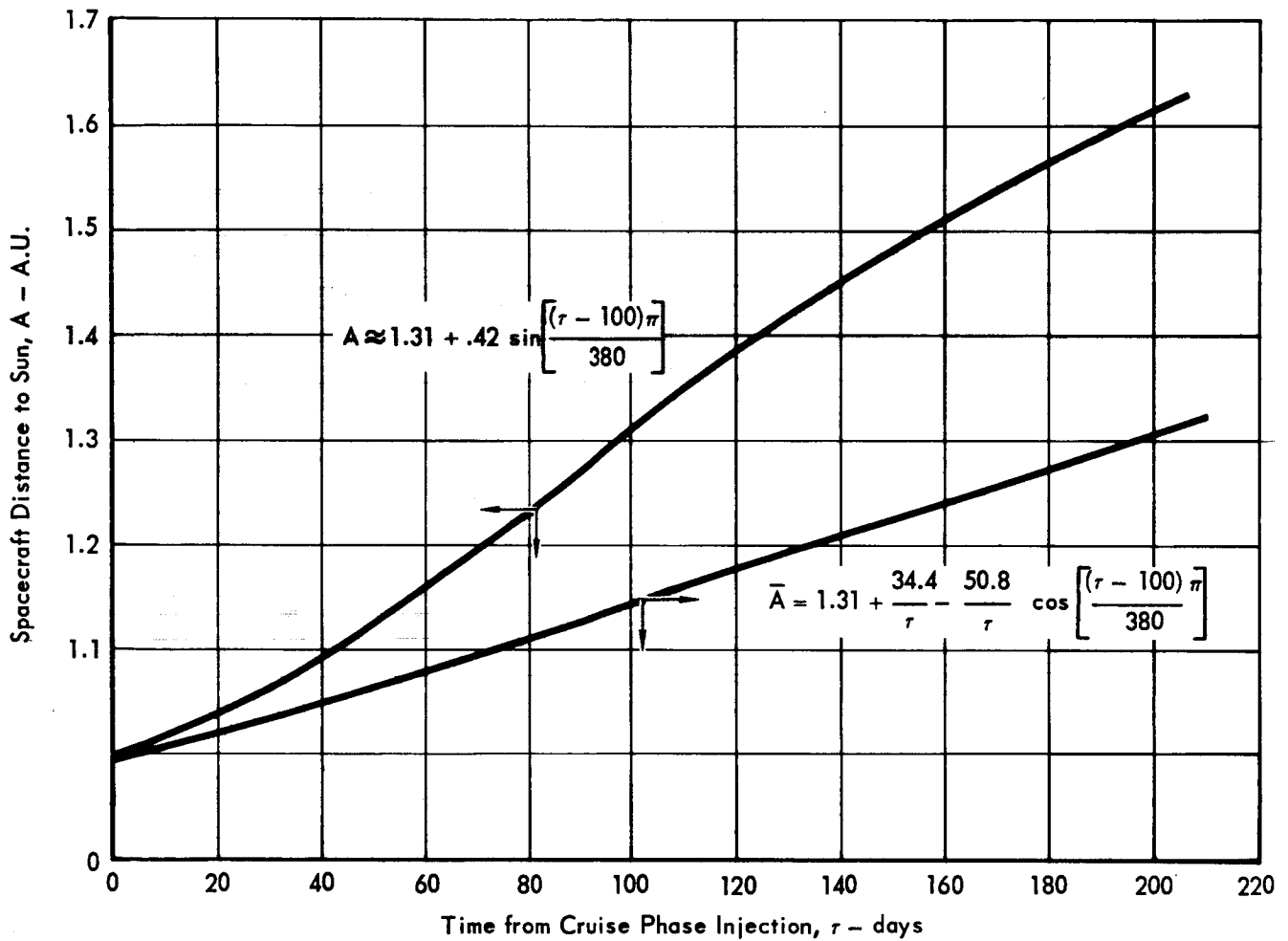
When the minimum mass that will penetrate the spacecraft is less than 10^{-2} gm, the meteoroid flux equation $N_{5,1}$ shall be used. Similarly, when the mass is greater than 10^{-2} gm, the meteoroid flux equation $N_{5,2}$ shall be used.

d. Shielding Factor - All the specific environments are applied to the exposed surface area of the canister. The exposed area is less than the total surface areas if a shielding body (e.g., Earth, Mars, or Flight Spacecraft) is present. The shielding afforded by the Earth or Mars for each mission phase is defined in Figure 1-12. Any additional shielding afforded by the Flight Spacecraft shall be used.

1.2.15 <u>Acoustical Noise</u> - The VOYAGER Flight Capsule launch configuration (Sterilization Canister, Shroud, Space Vehicle Station), negates acoustical noise as significant to Canister confined equipment level mission considerations.

1.3 STERILIZATION AND DECONTAMINATION - Each VOYAGER Flight Capsule shall be manufactured, assembled, tested, and encapsulated in such a manner as to enter the terminal sterilization cycle with less than 1×10^5 viable spores. The terminal sterilization cycle shall be such that the probability that a live organism will survive the sterilization is less than 10^{-3}.

Terminal sterilization of the VOYAGER Flight Capsule shall be by means of dry heat. The atmosphere internal to the Sterilization Canister during the heating cycle shall meet the following requirements:

a. A minimum of 97% nitrogen

b. A maximum of 2.5% oxygen

c. A maximum of 0.5% of gases other than nitrogen and oxygen

If decontamination must be generally employed to reduce the pre-sterilization spore population on the Flight Capsule to less than 1×10^5 viable spores, gaseous decontamination utilizing 12% ethylene oxide and 88 percent freon 12 shall be used (ETO).

Heat Sterilization and Ethylene Oxide (ETO) decontamination will be performed in Type Approach and Flight Acceptance Testing in accordance with the following paragraphs. Note: ETO decontamination and heat sterilization cycles are alternately performed.

1.3.1 <u>Piece Parts and Materials Compatibility</u>

a. ETO decontamination test (6 cycles) (stabilized at 50°C maximum for 28 hours of each 30 hour cycle).

b. Heat sterilization test (6 cycles) (stabilized at 135°C maximum for 92 hours of each 96 hour cycle).

1.3.2 <u>Subsystem (Assemblies) Type Approval (TA)</u>

    a. ETO (6 cycles) (stabilized at 50°C maximum for 26 hours of each 29 hour cycle).

    b. Heat Sterilization (6 cycles) (stabilized at 135°C maximum for 64 hours of each 76 hour cycle).

1.3.3 <u>Systems Type Approval (TA)</u>

    a. ETO of PTM (Test Cycle No. 1) (40°C for 2 hours followed by 25 hours at 50°C maximum of the 31.5 hour cycle).

    b. Final ETO of PTM (Test Cycles No. 2 and 3) (Stabilized at 50°C maximum for 27 hours of each 30 hour cycle).

    c. Heat Sterilization of PTM (Test Cycle No. 1) (125°C maximum for approximately 16 hours followed by approximately 53 hours of the 58 hour cycle).

    d. Heat Sterilization of PTM (Test Cycle No. 2) Stabilized at 135°C maximum for 60 hours of the 72 hour cycle).

    e. Heat Sterilization of PTM (Test Cycle No. 3) (Stabilized at 135°C maximum for 72 hours of the 84 hour cycle).

1.3.4 <u>Subsystem (Assemblies) Flight Acceptance (FA) (Flight Hardware)</u>

    a. ETO (1 cycle) (Stabilized at 40°C maximum for 24 hours of the 28 hour cycle).

    b. Heat Sterilization (1 cycle) (Stabilized at 125°C maximum for 60 hours of the 76 hour cycle).

1.3.5 <u>Systems Flight Acceptance (FA) (Flight Hardware)</u>

    a. ETO (none-performed at subsystem level)

    b. Heat Sterilization (none-performed at subsystem level)

1.3.6 <u>Terminal Sterilization</u> – The VOYAGER Flight Capsule terminal heat sterilization cycle shall have the following characteristics:

    a. Sterilization shall not require temperatures in excess of 125°C.

    b. The coldest contaminated point in the VOYAGER Flight Capsule shall not be subjected to conditions more severe than 125°C for 24.5 hours.

    c. The sterilization cycle shall be lethally time-temperature equivalent to 125°C for 24.5 hours.

    d. Thus, the sterilization cycle shall be 1 cycle at 125°C maximum temperature for 24.5 hours.

1. STRUCTURAL DESIGN CRITERIA - This appendix documents in detail the structural criteria used during the Phase B study. These criteria provide the framework for the expansion necessary to produce the detailed criteria data for hardware development in subsequent phases.

2. DEFINTIONS OF STRUCTURAL TERMINOLOGY - The following definitions include structural terms used in the criteria, loads and associated structural analyses. All weight data are in Earth pounds and accelerations in Earth g's unless otherwise noted.

a. Factor of Safety - The factor of safety is an arbitrary factor to account for such items as uncertainties and variations in material properties, fabrication quality, and internal and external load distributions.

b. Structural Corridor - The structural corridor is the envelope of design trajectories for which strength is provided.

c. Limit Load - Limit load is the maximum anticipated load the structure is expected to experience during a specific segment of a mission performed in a specified environment.

d. Ultimate Load - Ultimate load is obtained by multiplying the limit load by a factor of safety.

e. Predicted Temperature - The predicted temperature is the computed temperature based on dispersed trajectories.

f. Design Temperature - The design temperature is the initial entry temperature plus the predicted temperature rise increased by an arbitrary factor to account for uncertainties.

g. Combined Requirements - Limit loads are combined with design temperature of ultimate loads are combined with predicted temperatures, whichever is more critical.

h. Proof Pressure - Proof pressure is the pressure which a vessel must sustain as a singular load at predicted temperature without yielding. It is the product of the maximum operating pressure and the proof factor of safety.

i. <u>Burst Pressure</u> - Burst pressure is the pressure which a vessel must
    sustain without rupture when applied as a singular load at predicted
    temperature. It is a product of the maximum operating pressure and
    the burst factor of safety.

3. DESIGN MASS PROPERTIES - The Capsule Bus design values used in the structural
analyses are shown in Figure 3-1. Detailed discussion of the derivation of
these data is presented in Section 5. The 1973 baseline entry configuration
ballistic parameter $(m/C_D A)$ of 0.3 was conservatively used for the structural
analyses.

4. BASIC CRITERIA - This section summarizes the items of basic criteria which
were used for all structural parametric and specific design analyses. A summary
of limit load factors discussed in subsequent sections is shown in Figure 4-1.

The Capsule Bus strength is based on the following criteria.

a. The structure shall withstand limit load with the structure at
    predicted temperature without detrimental deflections or yielding.

b. The structure shall withstand the following load-temperature combinations
    without failure: limit load with the structure at design temperature
    or ultimate load with the structure at predicted temperature, whichever
    is more critical. Effects of temperature gradients are accounted for
    by adding the thermal stress associated with predicted temperature to
    the stress which results from limit mechanical loads, and multiplying
    the resulting stress by the factor of safety for mechanical loads.

c. The predicted structural temperatures and heating rates are based on
    dispersed trajectories. The envelope of initial conditions for these
    trajectories is discussed in Section 5 of this Appendix. The design
    temperature for radiative structure is the initial entry temperature plus the
    predicted temperature rise multiplied by a temperature uncertainty
    factor of 1.15. The design temperature for ablative protected structure
    is the initial entry bondline temperature plus the predicted bondline
    temperature rise multiplied by a temperature uncertainty factor of
    1.25.

DESIGN MASS PARAMETERS
(1973 BASELINE)

MISSION PHASE	WEIGHT	C.G.	I_{YY}	I_{XX}	I_{ZZ}
	LB–EARTH	CAPSULE STA.	SLUG–FT^2		
Pre-Launch to Pre-De-Orbit	5000	147.3	2100	2150	3150
Pre-De-Orbit	4150	146.4	1300	1350	1700
Entry	3650	152.6	970	1010	1700
Aerodecelerator Deploy	3650	152.6	970	1010	1700
Terminal Propulsion Initiation	2700	150.9	425	470	770
Touchdown	2500	152.1	415	400	700

SUMMARY OF RIGID BODY LOAD FACTORS
AT THE FLIGHT CAPSULE C.G.

MISSION PHASE	LIMIT LOAD FACTORS (EARTH g's)		REMARKS
	LONGITUDINAL	LATERAL	
Ground Hoisting	±2.0		Applied independently along hoisting axis; pull-off angles up to 20 degrees.
Assembly	–	±1.2	Cantilevered condition with 360 degree roll capability.
Transportation-air	±3.0	±1.5	Aircraft axis reference; vertical L.F. – ±3.0 ; not simultaneously
Pre-launch	±2.0		Hoisting – Remarks same as Ground Phase
Launch Lift-off	2.1	±.65	All load factors to be multiplied by 1.2 for dynamic effects.
Max Dynamic Pressure	2.0	±.30	
S-IC End Boost	4.9	±.10	
S-IC Thrust Decay & Separation	–1.9	±.10	
Injection	1.5	±.25	S–IV B Second Burn
Interplanetary Cruise	1.0	±.25	Mars Orbit Insertion
Capsule De-orbit	1.1	Nil	De-orbit Propulsion
Capsule Entry $a = 0$ $a = 20°$	–21.5 –19.4	0 ±2.2	Maximum Dynamic Pressure Condition
Capsule Terminal Deceleration Parachute	–5.5	–3.9	
Terminal Propulsion	–2.5	Nil	
Capsule Landing	–10.0 –14.0	±10.0 0	Applied simultaneously at Lander c.g.

Note: (1) Phases for which the load factors are negligable are not included.

Figure 4–1

Capsule Bus stiffness shall be such that:

a. The Capsule Bus is contained within the dynamic envelope specified for launch, and

b. Dynamic coupling with the control modes of the spacecraft is minimized.

The factor of safety shall be 1.25 for all phases except landing or ground handling and transportation conditions which may be hazardous to personnel. These exceptions are tabulated in Figure 4-2. In the landing phase, deformations shall be such as not to constrain any of the post-landing operations.

All pressure vessels and lines and fittings shall be designed to the most critical condition based on these criteria. The pressurized compartment factors are applicable to canister design. The canister must be flightworthy structurally and functionally, and must meet the planetary quarantine requirements after being subjected to proof pressure.

The proof pressure test for the various pressure vessels can be conducted at room temperature if the vessel is critical for the sterilization phase, providing the pressure is increased to compensate for the loss in strength of the vessel due to temperature. Figure 4-3 presents the pressurization factors used in the structural analyses. All factors are used with nominal gages, and include the hazard factor specified in Paragraph 4.4.16.4 of the "1973 VOYAGER Capsule Systems Constraints and Requirements Document," dated 12 June 1967.

5. MISSION PHASES – The mission phase requirements applicable to the structural design of the Capsule Bus are defined in the following paragraphs.

a. <u>Ground Phase</u> – This phase includes operations such as hoisting, assembly, sterilization, and transportation prior to the pre-launch phase.

The Capsule Bus is hoisted either independently or as part of the Planetary Vehicle. The hoisting limit load factor is 2.0 applied along the hoisting axis with pull-off angles of up to 20 degrees in any direction relative to the hoisting axis, for local strength requirements.

Canister pressures during sterilization are controlled to preclude undue weight increases in the canister as a result or pressure increases during the sterilization cycles.

DESIGN FACTORS

FACTORS OF SAFETY

● Flight Conditions	1.25
● Ground Handling Conditions Potentially Hazardous to Personnel	1.50
● Emergencies in Air Transport Landing (MIL–A–8421B)	1.00
● Landing System Structure for Mars Landing Condition	1.00

TEMPERATURE FACTORS

Radiative Structures

● Predicted Temperature – Temperature determined from dispersed trajectories.

● Uncertainty Factor – 1.15

● Design Temperature = Initial Entry Temperature + (1.15 x Predicted Temperature Rise)

Ablative Structure

● Predicted Temperature = Temperature determined from dispersed trajectories.

● Uncertainty Factor = 1.25

● Design Temperature = Initial Entry Temperature + (1.25 x Predicted Temperature Rise)

PRESSURIZATION FACTORS

Operating	PROOF	BURST
• Pressurized Compartments	1.33	1.67
• Pneumatic Vessels	1.67	2.22
• Hydraulic Vessels	1.50	2.50
• Lines and Fittings	2.0	4.0
Sterilization (1)		
• Pressurized Compartments	1.05	1.25
• Pneumatic Vessels	1.25	1.50
• Hydraulic Vessels	1.25	1.50
• Lines and Fittings	1.67	2.40

Notes:
(1) Sterilization factors shall be applied to the pressure resulting from the heat of the sterilization cycle or solar heating during the pre-launch phase, whichever is more critical. The pressure shall include the effects of temperature rise, vapor pressure, and other chemical reactions of the enclosed gas or fluid that occur during the cycle.

Figure 4–3

The transportation requirements of MIL-A-8421B are applicable, but
testing per this specification is not required. Ground handling equipment
is designed to minimize the weight increases to flight hardware as a
result of ground phase conditions.

b. Pre-Launch Phase - The pre-launch phase begins with arrival of flight
    hardware at KSC and terminates at the start of final countdown. The
    primary considerations during this phase are hoisting, accelerations
    incurred during crawler-transporter operations, ground winds, and gusts.
    The requirements defined for the Saturn V during this phase are used
    as a basis for the spacecraft requirements. Hoisting requirements are
    as specified for the ground phase.

c. Launch Phase - The launch phase begins with the initiation of final
    countdown and ends with initiation of S-IVB stage second burn. Saturn V
    design launch conditions are used as a basis for capsule launch condi-
    tions. These conditions include the effects of ground winds, gusts,
    and control system operation during the transition from the restrained
    cantilevered condition to free-flight.

    The design trajectory longitudinal and lateral load factor time
    history for the first stage of ascent is presented in Figure 5-1.
    Figure 5-2 presents the envelope of combinations of longitudinal and
    lateral factors used for capsule design. For conditions where transient
    forces are significant, a factor of 1.2, applicable in any direction,
    shall be used to account for the local dynamic response of the capsule
    during the launch phase, pending the results of dynamic analyses.

    The design of the canister shall incorporate a venting system,
    consistent with the planetary quarantine requirements, in order to
    control canister differential pressures during ascent. A positive
    differential pressure, relative to the shroud internal pressure,
    shall be maintained during ascent. The canister and adapter shall
    be designed for zero pressure differential or the pressure associated
    with a specific venting design, whichever is more critical. The
    effects of internal pressure shall not be used when these effects
    relieve primary loads and shall be used when they add to the primary
    loads.

LIMIT LATERAL AND LONGITUDINAL LOAD FACTOR
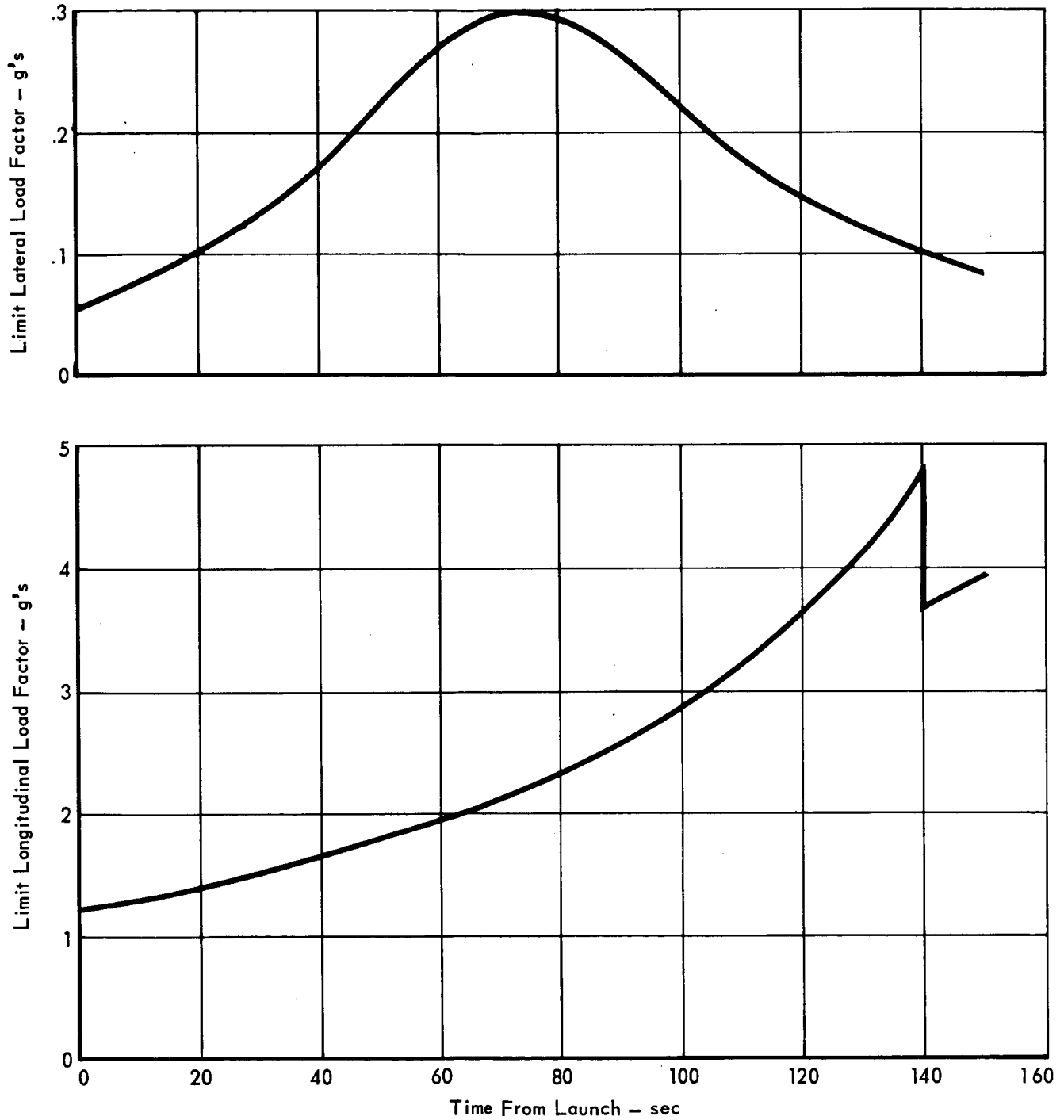## VS. TIME FROM LAUNCH
SATURN V (1ST STAGE)

Time From Launch — sec

DESIGN ENVELOPE FOR FLIGHT CAPSULE
COMBINED LIMIT LOAD FACTORS
(LAUNCH PHASE)

CONDITION NUMBER	LAUNCH VEHICLE	FLIGHT CONDITION
*1	Saturn V	Lift Off
*2	↓	Maximum Dynamic Pressure
*3		S–IC End Boost
*4	Saturn V	S–IC Thrust Decay & Separation

Note:

*Dynamic factor of 1.20 in any direction to be used.

Radial or Lateral Load Factor – g
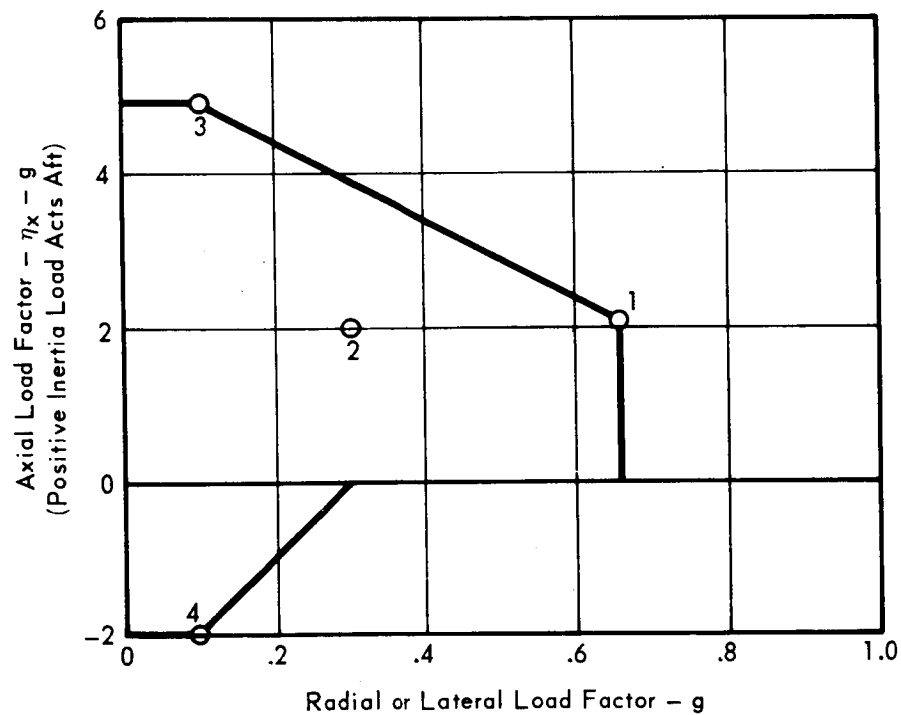
d. <u>Injection Phase</u> - The injection phase begins with initiation of the S-IVB stage second burn and terminates when the aft planetary vehicle is separated from its adapter. Operations included in this phase are: (1) S-IVB second burn which provides velocity increment to inject the planetary vehicles into a specified interplanetary transfer trajectory, (2) separation of the forward planetary vehicle, (3) separation of shroud elements forward of the aft planetary vehicle, and (4) separation of the aft planetary vehicle, all with sufficient velocity to ensure that no interference occurs between any of the ejected elements.

The meteoroid environment of Appendix A shall apply during this phase.

e. <u>Acquisition Phase</u> - The acquisition phase begins with PV separation and ends when the vehicle attitude is stabilized on its celestial attitude references. Mission operations of this phase are concerned mostly with tracking and data acquisition.

The meteoroid environment of Appendix A shall apply during this phase.

f. <u>Interplanetary Cruise Phase</u> - The interplanetary cruise phase begins when the vehicle is stabilized on its celestial attitude reference and ends about seven days prior to the Mars orbit insertion. Mission operations during this phase consist of the Arrival Date Separation Maneuver, Trajectory Correction Maneuvers, and the Mars Orbit Insertion Maneuver. The loads for Capsule Bus shall be based on a maximum transient thrust deflection of the Spacecraft primary propulsion unit.

The meteoroid environment of Appendix A shall apply during this phase.

g. <u>Spacecraft-Capsule Separation Phase</u> - The Spacecraft-Capsule Separation extends from the time the flight capsule subsystems are activated for separation until the capsule thrust axis is oriented for the de-orbit maneuver. The major mission operation occurring in this phase is the separation of the capsule from the spacecraft. This separation must occur without the need for a spacecraft maneuver, and the Capsule must make a low velocity separation with no recontact.

The meteoroid environment of Appendix A shall apply during this phase.

h. <u>Capsule De-Orbit Phase</u> - This phase begins when the capsule is oriented for de-orbit and ends with the completion of the de-orbit propulsion maneuver. The major mission operation is the de-orbit thrusting.

The meteoroid environment of Appendix A shall apply during this phase.

i. Capsule Orbital Descent - The capsule orbital descent extends from the
    termination of de-orbit thrust to entry at 800,000 feet altitude. Since
    this phase is concerned mainly with performing the required pre-entry
    functions, there are no significant structural requirements. However, the
    meteoroid environment of Appendix A is applicable.

j. Capsule Entry - The Capsule Entry phase begins at 800,000 feet and ends
    with initiation of the terminal deceleration phase.

    The combinations of initial entry velocity and flight path angles for
    design are presented in the V-γ entry envelope, Figure 5-3. Trajectories
    for conditions bounded by this envelope are considered to be dispersed
    trajectories which define the entry structural corridor.

    The baseline entry configuration is a 60 degree sphere-cone with a
    19 foot diameter. The ballistic parameter ($m/C_D A$) is .3 slugs/ft^2 for
    structural analyses. Design entry trajectories for maximum loads and
    maximum total heat are presented in Part B, Section 2 for critical points
    on the V-γ entry envelope. The VM-3 and VM-8 atmospheres are used for
    maximum total heat and maximum loads trajectories, respectively. The
    variation of maximum dynamic pressure and axial load factor with $m/C_D A$
    is presented in Figure 5-4 for the load-critical entry conditions and
    atmosphere.

    A design angle of attack of 20 degrees at maximum dynamic pressure
    was used for preliminary analyses. This value is intended to account for
    single malfunction conditions, entry anomalies, winds and gusts, and is
    used with the dispersed trajectories which define the entry corridor.

k. Terminal Deceleration Phase - The terminal deceleration phase begins with
    aerodynamic decelerator deployment and ends with touchdown. The require-
    ments shall include those imposed by decelerator deployment, aeroshell
    separation, and terminal propulsion operation. The wind shear and gust
    data of Appendix A shall be used for aerodynamic decelerator stability
    analyses and dispersion studies for the terminal propulsion system.

l. Landing Phase - The landing phase begins with touchdown and ends with
    completion of the post-landing Capsule Bus and entry data transmission.
    The terrain and slopes specified in Figure 5-5 shall apply. The Lander is
    required to be stable for touchdown on both planar and conical surfaces

DESIGN ENVELOPE FOR ENTRY VELOCITY AND
FLIGHT PATH ANGLE
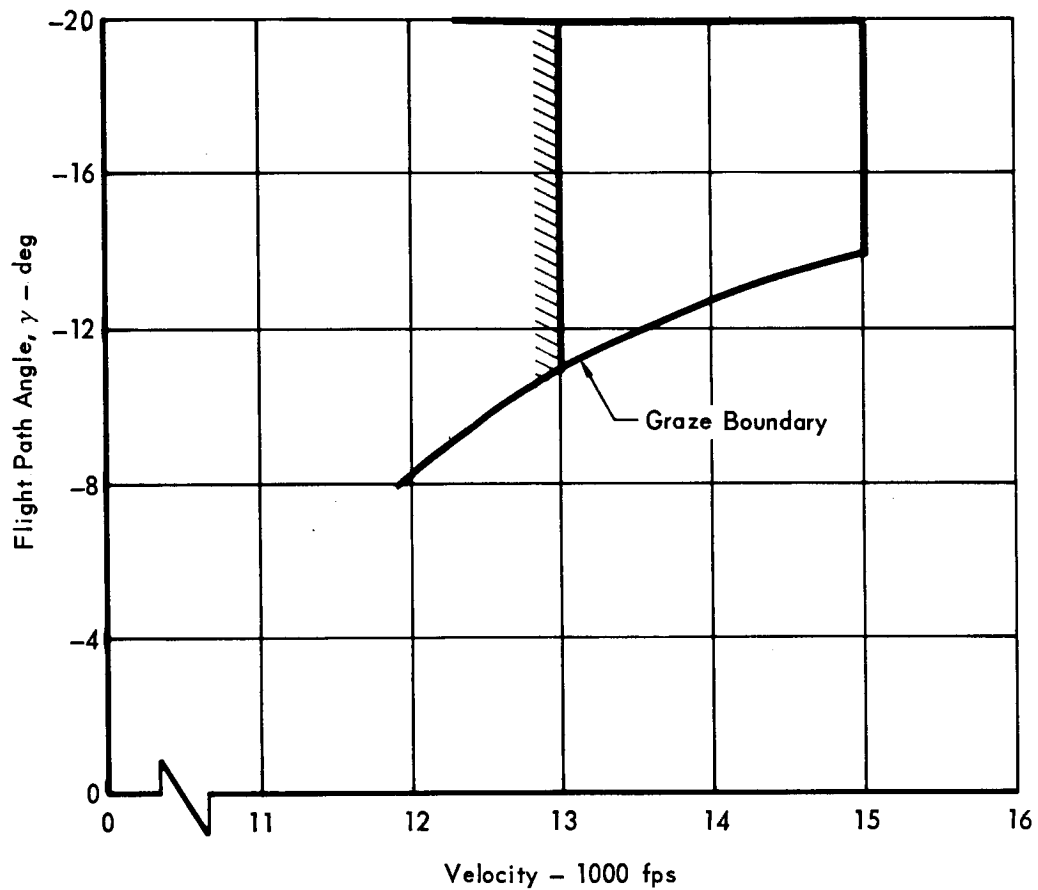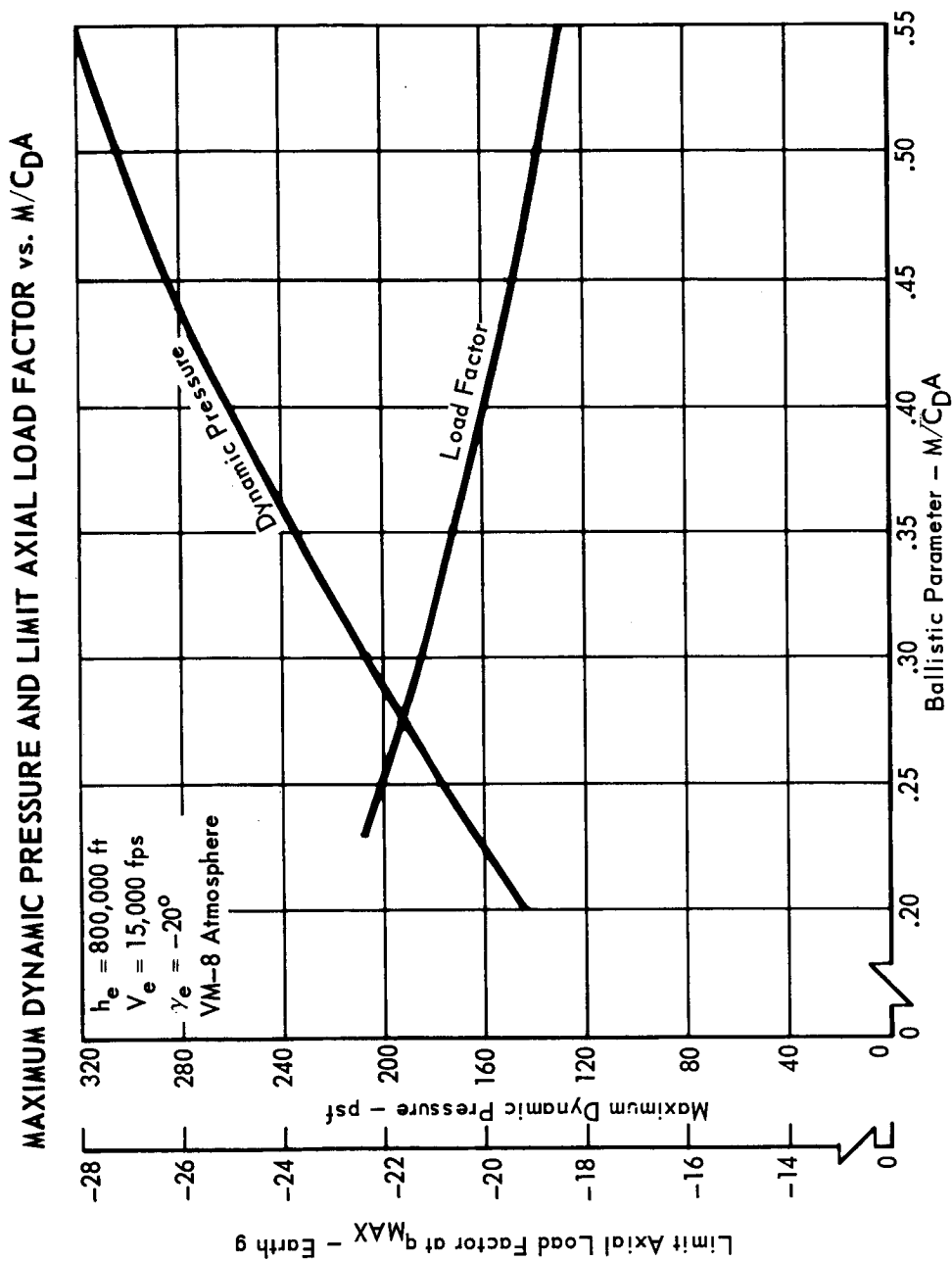
Note:
Entry Altitude = 800,000 ft

Graze Boundary

Flight Path Angle, γ – deg

Velocity – 1000 fps

MAXIMUM DYNAMIC PRESSURE AND LIMIT AXIAL LOAD FACTOR vs. M/C_DA

Figure 5-4

LANDING PARAMETERS

INITIAL CONDITIONS	NOMINAL	EXTREME VARIATION
• Velocities		
Vertical — fps	16	± 4
Horizontal — fps	± 5	± 5
Pitch Rate — deg/sec	0	± 7
Yaw Rate — deg/sec	0	± 7
• Attitudes		
Pitch — deg	0	± 10
Yaw — deg	0	± 10
• Surface		
Continuous Slopes — deg	± 34	
⁺Abrupt Slope Changes — deg	± 68	
Bearing Capacity — psi	6 to ∾	
Friction Coefficient	.3 to 1.0	
Surface Rocks — in.	5.0	
Length of Surface Slope	324 ft for 34 deg Slope 6480 ft for 10 deg Slope	

⁺Local slopes shall not exceed ± 34 deg relative to the horizontal.

with slopes and initial conditions as specified in Figure 5-5; however, only one parameter shall be at the extreme with all other parameters nominal. The load requirements for the Surface Laboratory for landing shall not exceed the requirements imposed by prior mission phases.

m. <u>Landed Operations</u> - This phase begins with activation of the Surface Laboratory and ends with the last data transmission. The primary requirements results from wind loads on the Lander and associated extendable experiment units. The design surface winds described in Appendix A apply and the lander shall maintain its position in the presence of these winds.